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Science Focus

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HOW ANTIMATTER WORKS

The truth about
WHY WOMEN'S PAIN IS UNDERTREATED

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even in the winter, is good for you

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FROM THE EDITOR



Welcome to our 400th issue!

Don't worry, I'm not about to bore you with a tedious trip down memory lane. I enjoy nostalgia as much as the next person, but droning on about the past just didn't seem right for a magazine that's been navigating the bleeding-edge of science and technology for over three decades. No, it only seemed right to look forward, as we always have, to the future. So, that's exactly what we've done for this issue! Inside, we've explored some of the subjects that have been most popular with you – our readers – in the format that's been most popular: a great, big Q&A.

Of course, we haven't been exhaustive. We need to leave something for the next 400 issues. But we'd like to think we've mixed together a great science cocktail for you to enjoy over the start of the new year.

Naturally, there wouldn't be 400 issues without you, the readers. However you've engaged with us over the years – via print, online or through our podcast – you are the reason we exist. So rather than us tell you about the last 400 issues, we'd really love to hear what the magazine has meant to you over the years, and what you might like to see more of in the future. Either find us on your favourite social media website, whether that's Facebook, X (formerly Twitter) or Instagram, or just fire us an email at reply@sciencefocus.com.

Hope you enjoy the issue, and here's to 400 more!

Daniel Bennett

Daniel Bennett, Editor

WANT MORE? FOLLOW SCIENCEFOCUS ON FACEBOOK X (FORMERLY TWITTER) PINTEREST INSTAGRAM

ON THE BBC THIS MONTH...



Attenborough and the Giant Sea Monster

One of the most formidable predators the planet has ever seen, hunted just off the coast of Dorset. Sir David joins fossil experts to excavate a giant skull belonging to a pliosaur, the *T.rex* of the sea, to tell the story of the UK's prehistoric era.

BBC One, 1 January

Also available on BBC iPlayer

Just One Long Thing

If you can't get enough of Michael Mosley's brief-but-brilliant looks at the changes that can lead to a healthier lifestyle, you're in luck. In this special series, he dives deeper into them, starting with the pursuit of happiness.

BBC Radio 4, 1 January, 12pm

Also available on BBC Sounds



Obsessed with the Quest

Rounding out a bumper day of science on the BBC is this new series. It shares tales of dangerous expeditions with narrow escapes, told first-hand by the scientists and naturalists chasing big breakthroughs.

BBC Radio 4, 1 January, 1:45pm

Also available on BBC Sounds

Is it true that gorillas are permanently flatulent? → p85



CONTRIBUTORS



PROF SARAH ALLINSON

Sarah studies the effects of DNA damage on cells. She takes us through the latest exciting research that could help us beat cancer. → p74



DR HAYLEY WRIGHT

As the years go by, most of us end up losing a step or two mentally. Cognitive ageing expert Hayley shares tips on how to keep our minds sharper for longer. → p76



PROF HENRY T GREELY

Henry, a professor of genetics at Stanford University, explains how babies of the future could be made – and the implications for sex. → p68



DR JONATHAN FOLEY

Environmental scientist Jonathan advises the world's governments on ways to reduce emissions. He delves into climate change and the fixes we already have. → p71

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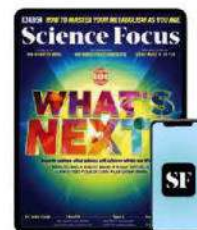
The tech that's delivering the future... today.

**34****DR KATIE MACK**

“WHATEVER WE CALL THE MATTER WE HAVE, WE SEEM TO BE LUCKY THAT IT EXISTS”

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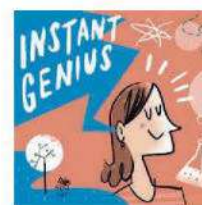
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THE BEST SCIENCE IMAGES OF 2023

A PIECE OF ROCK BROKEN OFF AN ASTEROID HURLING THROUGH SPACE, THE FIRST FOOTPRINTS OF HUMANS ARRIVING IN NORTH AMERICA AND A GIANT MEATBALL MADE OUT OF WOOLLY MAMMOTH. THESE ARE JUST SOME OF THE IMAGES THAT CAUGHT THE ATTENTION OF *BBC SCIENCE FOCUS* EDITORS THIS YEAR, AND NO, THAT LAST ONE WASN'T A MISTAKE. ENJOY OUR SELECTION OF IMAGES THAT HAD US RUBBING OUR EYES IN DISBELIEF IN 2023.

by HAYLEY BENNETT

Rocket science

BOCA CHICA, TEXAS, USA
NOVEMBER

SpaceX, the spacecraft manufacturer founded by Elon Musk, conducted two tests of its reusable Starship system in 2023. Standing 121m (397ft) tall, it's twice the height of NASA's Space Shuttle and incorporates the world's most powerful rocket to date. The system has two stages: a passenger-carrying section on top (the second stage) and a rocket below (the first stage), powered by 33 methane and liquid oxygen-fuelled engines. Its maiden test flight (uncrewed) in April not only saw the system explode three minutes after launch, but the thrust from its engines also caused significant damage to the launchpad (see inset). Its subsequent uncrewed test flight in November saw the second stage reach space successfully. Although it's believed to have self-destructed shortly afterwards, however.



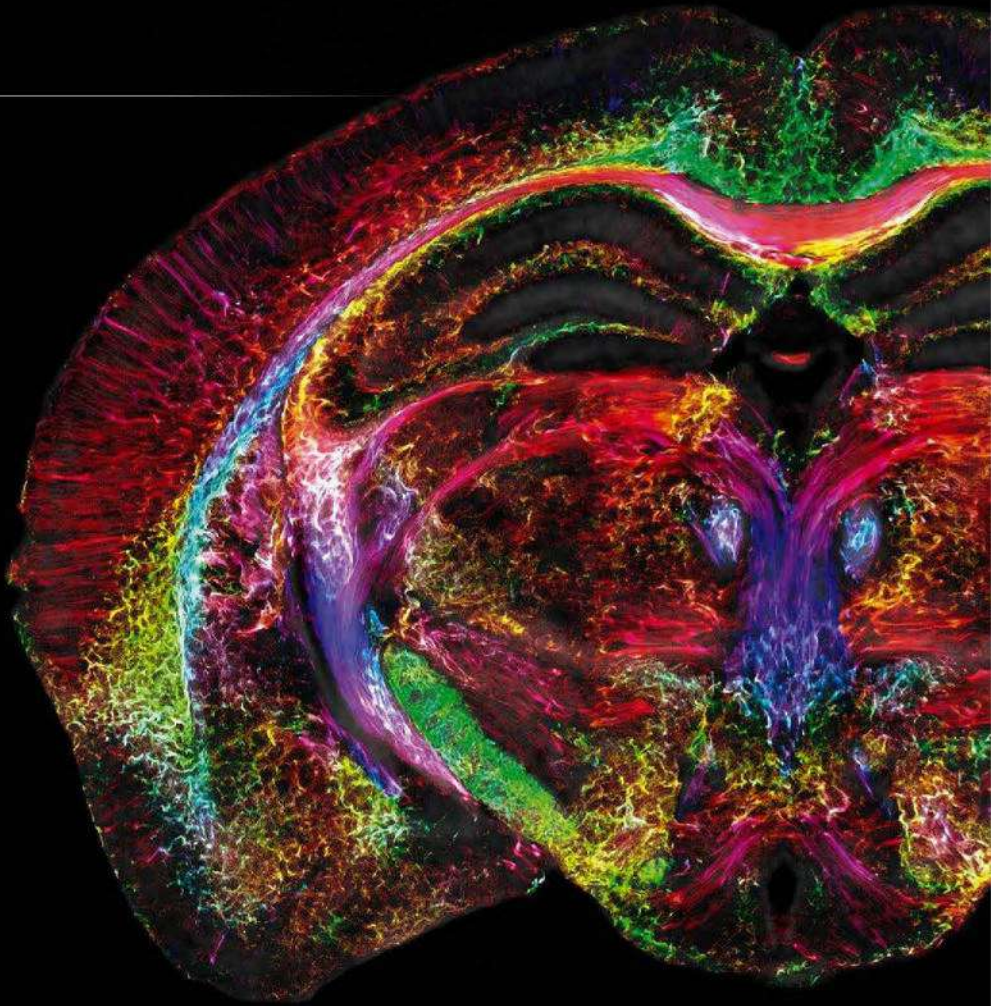
SPACEX GETTY IMAGES



In greater detail

NORTH CAROLINA, USA
APRIL

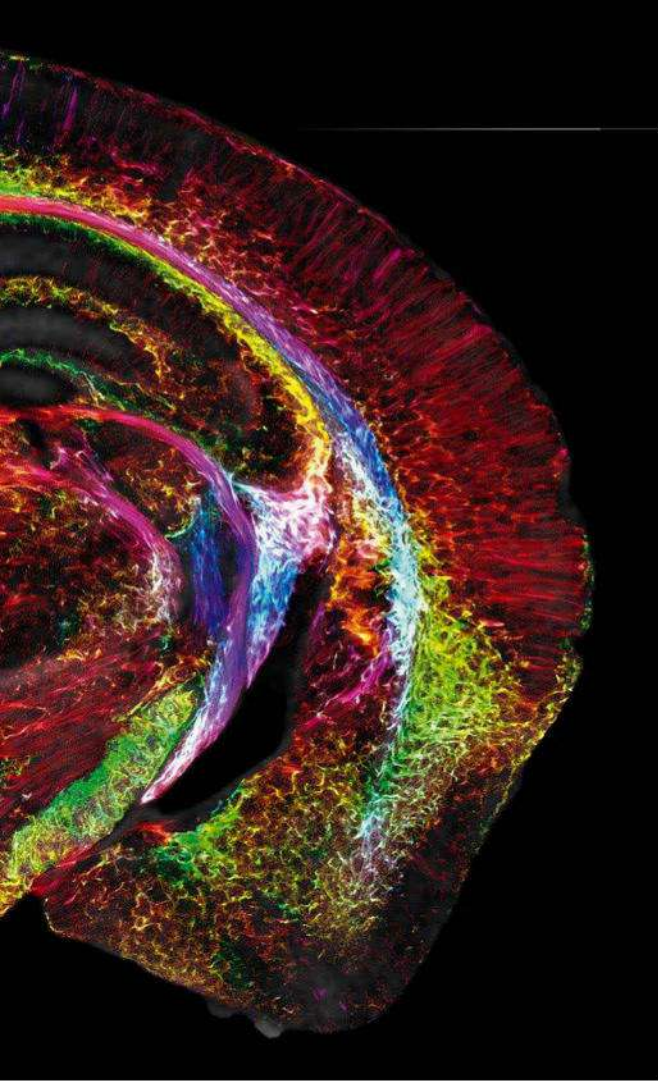
50 years ago, the Nobel Prize-winning chemist Paul Lauterbur described a new imaging technique in the journal *Nature*: magnetic resonance imaging (MRI). The technique remains at the forefront of modern medical diagnosis, but for the last four decades, researchers at Duke University in the US have been striving to improve it. This year, they showcased their results with this super-high-resolution image of a mouse brain, made possible by a combination of stronger magnets and more powerful computers. Each voxel in the image (the equivalent of a pixel in 3D) is 64 million times smaller than in a standard MRI.



A rare visit

FEBRUARY

Opportunities to photograph the 'Green Comet', Comet C/2022 E3 (ZTF), don't come around too often. It's an infrequent visitor to our corner of the Solar System, taking 50,000 Earth years to do a lap of the Sun and was last visible during the Stone Age. In February, however, it completed another circuit, passing within 43 million kilometres (26 million miles) of Earth and appearing in the constellation Camelopardalis. The comet's green hue is thought to be due to sunlight bouncing off diatomic carbon (molecules containing two carbon atoms stuck together) in the gases streaming from its surface. By the New Year, it'll already be over 680 million kilometres (422 million miles) away from Earth.



Parachuting in

MIZORAM, INDIA

JUNE

Lizard lovers crooned when this picture showing a newly discovered species of parachuting gecko made the news. It's one of a number of species previously classified as Ptychozoon (parachute geckos), which have skin flaps allowing them to glide from tree to tree. The whole group was recently reclassified under plain old *Gekko*, with the new species christened *Gekko mizoramensis* after its native home in the Mizoram state of northeast India. Found in a region of forest that crosses into Myanmar and Bangladesh, a specimen of it was collected two decades ago, but mistaken for a different species. The researchers claim its discovery highlights the 'poor state of biodiversity documentation' in the region.

DAN VAHABA/DUKE INSTITUTE, OSCAR MARTÍN MESONERO/STARTRAILS.ES/ESA, ZEESHAN A MIRZA







Hot spot

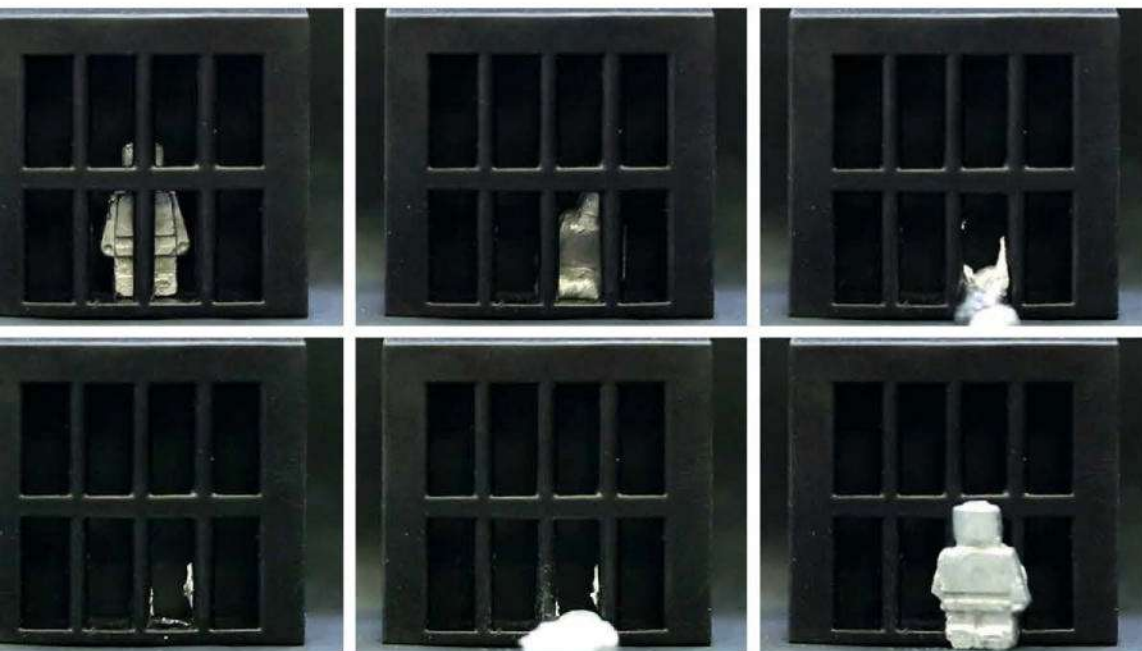
HAWAII, USA
JANUARY

Hawaii's Kilauea volcano is one of the world's most active, rarely staying silent for more than a few weeks or months at a time and never – in the last couple of centuries, at least – for longer than 18 years. An eruption in January marked its awakening from a brief slumber over the Christmas and New Year period. Prior to that, it had been on the go since September 2021. This image shows the Halema'uma'u Crater, where 50m-high (164ft) lava fountains were seen on 5 January. The crater formed when a lava lake in the volcano's caldera emptied out at the end of the 19th century. It doubled in size after a particularly destructive eruption in 2018.

Special delivery

HOUSTON, TEXAS, USA
SEPTEMBER

On 24 September, NASA's OSIRIS-REx spacecraft swung by Earth to drop off a package, then continued on with its mission to explore nearby asteroids. This is what scientists discovered when they opened the capsule that OSIRIS-REx sent parachuting down to the Utah desert: rock dust (right of centre) that the spacecraft collected from the 500m-wide (1,600ft), near-Earth asteroid Bennu. Now under scrutiny in a NASA clean room, in October, the results of initial analyses hinted that the dust is rich in carbon and water. Bennu is thought to be a piece of a much larger, ancient asteroid – scientists view it as a time capsule containing information about the origins of our Solar System.



Narrow escape

PENNSYLVANIA, USA
JANUARY

In January, researchers from Carnegie Mellon University pulled off this jailbreak scene – a nod to 1991's *Terminator 2* – by making a figurine out of a new type of material that melts in a magnetic field. It's a feat that's arguably less impressive than it appears, as the material, which contains tiny magnetic particles embedded in gallium, had to be recast in a mould to reform the figurine in the final shot. Full marks for presentation though.

Under pressure

FLORIDA, USA
MAY

Between March and June, marine researcher Joseph Dituri (pictured) spent a record-breaking 100 days in Jules' Undersea Lodge, named for the author Jules Verne. Submerged 7m (22ft) below the surface of a Florida lagoon, his body apparently thrived in the extreme environment (where the pressure is kept at the same level as the water outside), with his cholesterol and inflammatory markers both taking a nosedive. Speaking afterwards, Dituri said, 'It was about... extending human tolerance for the underwater world.'



Heading south

TYNE AND WEAR
APRIL

On a clear night, the aurora borealis can be seen above the Arctic Circle (67° north). But in late April this year, people living further south, including near Whitley Bay (55° north) (pictured) in England, were treated to spectacular displays. Also known as the northern lights, the aurora is the result of charged particles expelled from the Sun crashing into Earth's atmosphere. This 'solar wind' is linked to sunspot activity that's currently increasing towards a 'solar maximum' predicted for 2025, meaning we can expect to see the aurora at lower latitudes for a couple more years.





Step back in time

NEW MEXICO, USA
OCTOBER

Until recently, scientists thought humans arrived in North America 13,000–16,000 years ago. But in 2021, radiocarbon dates for fossilised footprints (pictured) discovered in 2009, in the White Sands National Park in New Mexico, moved their arrival back to 21,000–23,000 years ago. Controversy raged around the dating, however, which was based on seeds embedded in the prints. So the researchers started again, this time collecting 75,000 grains of pollen from the footprints and using both radiocarbon and optically stimulated luminescence dating. In October, they reported the results. Their conclusion? They were right the first time.



Storm damage

DERNA, LIBYA
SEPTEMBER

On 10 September, Storm Daniel hit Libya, causing catastrophic flooding in the city of Derna. Over 4,300 people were killed in the storm and its aftermath, according to the World Health Organization, while ten times as many fled their homes. The coastal city was hit by flash floods when two dams burst under pressure from torrential rains. In November, Libyan scientists reported that water sources had been contaminated following damage to water and sewage systems, and noted that 55 children in Derna had suffered from waterborne diseases. The scientists also called for international efforts to help avoid public health crises after natural disasters in conflict-affected countries such as Libya.



Window on the past

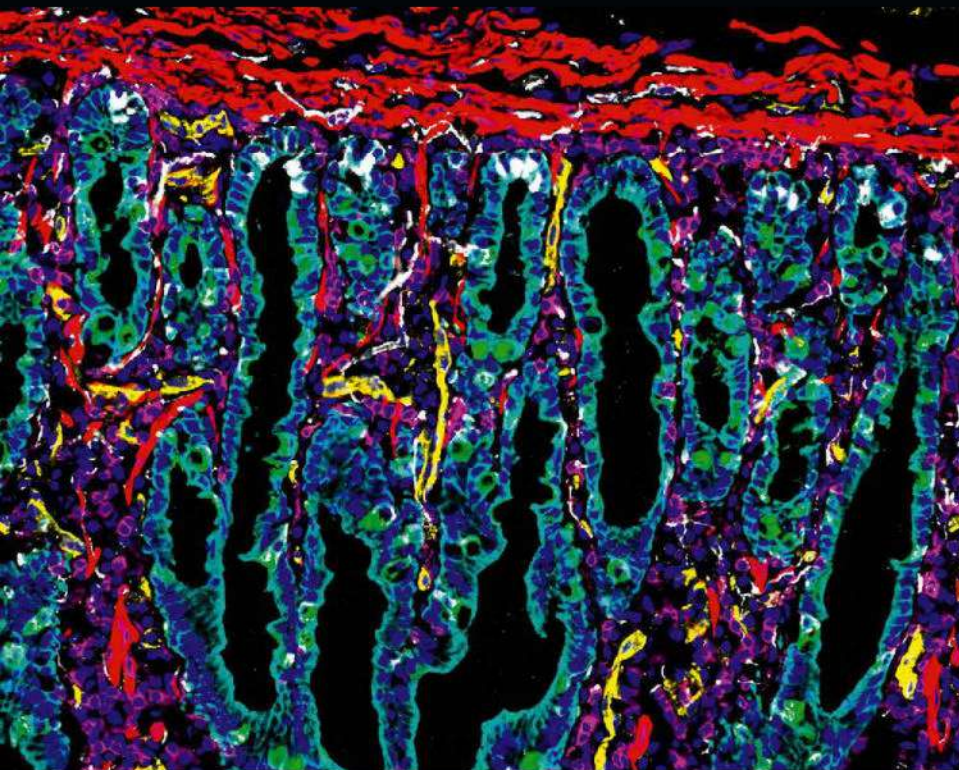
COLMAR, FRANCE
MARCH

It may not be Jurassic, or contain dinosaur DNA, but this piece of amber that went on display in France's Natural History and Ethnography Museum in March contains a very old and very unusual snail. Research published in October 2022 identified the preserved snail as *Archaeocyclotus brevivillosus*, a previously unknown species dating to approximately 99 million years ago and distinguished by its hairy shell. The amber it's contained in came from the Hukawng Valley in Myanmar in 2017. Over 2,000 species have been found trapped in 'Burmese amber', including spiders with tails and worms with legs.

Clear skies with a chance of rhino

SOUTH AFRICA
JUNE

Twenty years ago, the World Wide Fund for Nature (WWF) collaborated with governmental organisations in South Africa to start the Black Rhino Expansion Project. Today, WWF says the project has created 15 new rhino populations. Meanwhile, figures announced by the African authorities in September 2023 suggest there are now nearly 6,500 black rhinos across Africa, up from less than 2,500 in the mid-1990s, when populations had dwindled due to the killing of rhinos for their horns. The project continues to establish new rhino populations and, in December, featured in *Planet Earth III*, which showed how difficult it is to transport an 800kg-plus (1,900lb) animal to its new home.



Show your guts

STANFORD, CALIFORNIA, USA
JULY

Most of us don't think too deeply about how our nine metres (30ft) of intestines are organised, except when they're in knots. But take a closer look at this colourful image unveiled by US, Swiss and German scientists in July, and you might start to realise what a complex and well-ordered organ the gut really is. Each colour in this image represents a different molecule, which has been highlighted by washing the gut tissue with a fluorescent antibody specifically designed to stick to that molecule. By combining several new imaging techniques, the scientists were able to map 20 'neighbourhoods' of gut cells by visualising their molecular contents, at the level of the individual cell, for the first time.

BBC STUDIOS, NASA/ESA/CSA, STANFORD MEDICINE/SNYDER LAB/NOLAN LAB/GREEN LEAF LAB

Beacons in the night

JUNE

Two very bright stars in the Orion Nebula draw the eye in this image captured by the James Webb Space Telescope's near-infrared camera. But it's the smaller stars, and what surrounds them, that interest scientists. Released jointly by ESA, NASA and the Canadian Space Agency in June, the image shows an area where young stars are being born within rotating clouds of dense gases and dust (protoplanetary discs) from which planets may later emerge. Data from the telescope allowed scientists to detect a molecule known as the methyl cation in a protoplanetary disc for the first time. This molecule may be crucial to the chemical processes involved in creating organic molecules, upon which life depends.



Good luck, have fun

CAPE CANAVERAL, FLORIDA, USA
MARCH

Good Luck, Have Fun, or rather GLHF, was what the rocket company Relativity Space named its mission to launch the first 3D-printed rocket into space. The rocket, Terran 1 (pictured), launched in March, successfully making it past the 100km-high (62 miles) Kármán line, which marks the point where Earth's atmosphere meets space. But while GLHF was billed as a happy-go-lucky maiden voyage for the Californian company, it has its sights on more serious missions. By 2026, Relativity Space expects to be using its 3D-printed rockets to launch customer satellites from the Florida site that once saw the Apollo spacecraft take flight. Its long-term goal is to create an industrial base on Mars.

The truth is out there

BURSA, TURKEY
JANUARY

Some people might question the credibility of this photo, and many did when it appeared on social media in January. It's not, as you might imagine, an AI-created UFO; it's actually a cloud. Specifically, a 'lenticular' (lens-shaped) cloud that just happens to look like it could be a vessel carrying visitors from another planet. Lenticular clouds are thought to be responsible for numerous UFO sightings. If you've never seen one, it's probably because you don't live near mountains. Lenticular clouds are the result of peculiarities in how air and water vapour move across a mountain range.



JOHN KRAUS/RELATIVITY SPACE, GETTY IMAGES, REUTERS



Meat boulder

AMSTERDAM, THE NETHERLANDS
MARCH

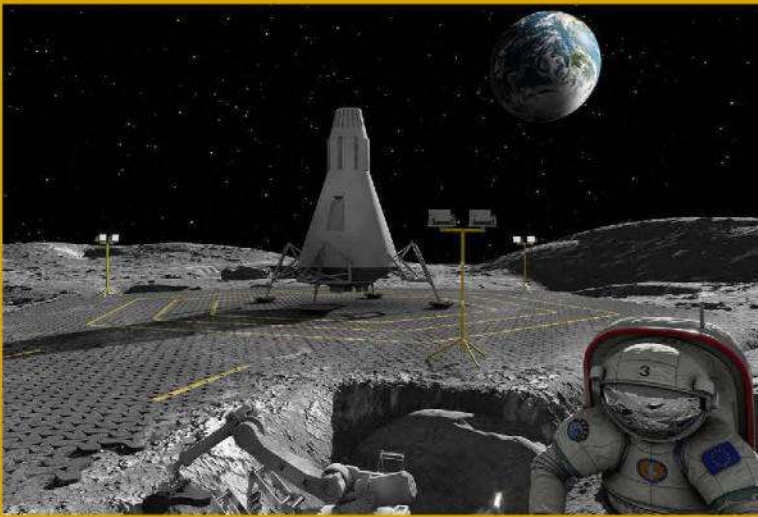
Devotees of the caveman diet will be intrigued by this epically proportioned meatball containing woolly mammoth protein. Cooked up by Vow, an Australian company that produces lab-grown meat, it's made from sheep stem cells into which scientists inserted a mammoth gene sequence (patched up with elephant DNA) that codes for the myoglobin – the protein that makes red meat look red. Although eating this meatball is ill-advised, as no one knows what 4,000-year-old proteins might do to our immune systems, it does make you wonder what future delicacies we might have to look forward to. Anyone fancy a *T. rex* toastie?

FEEDBACK

YOUR OPINIONS ON
SCIENCE, TECHNOLOGY
AND OUR MAGAZINE

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LETTER OF THE MONTH



Don't inhale

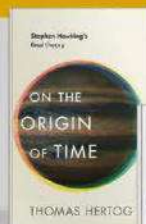
In your story headlined 'Scientists plan to melt Moon dust to lay lunar roads' (November, p16), you mention how damaging the dust on the Moon can be – how it eroded the spacesuits worn by the Apollo astronauts and the hazard it might present for future lunar missions. Did the Apollo astronauts suffer any long-term health effects from exposure to the dust they brought back into the lunar module on their suits and boots?

Alan Thomas, Middlesex

Editor Daniel Bennett replies All the Apollo astronauts that walked on the Moon suffered sore throats, itchy eyes and sneezing in the days after taking their small steps and giant leaps for mankind – symptoms that were christened 'lunar hay fever'. As for long-term effects, I'm not aware of any that have been reported. Although a study published in 2018 showed that lunar soil simulants can destroy lung and brain tissue after long-term exposure.

WRITE IN AND WIN!

The writer of next issue's *Letter of the Month* wins a pair of hardback popular science books. Put pen to paper (or fingertips to keyboard) and you could get your hands on *The Warped Side of Our Universe* by Kip Thorne and Lia Halloran, and *On the Origin of Time* by Thomas Hertog.



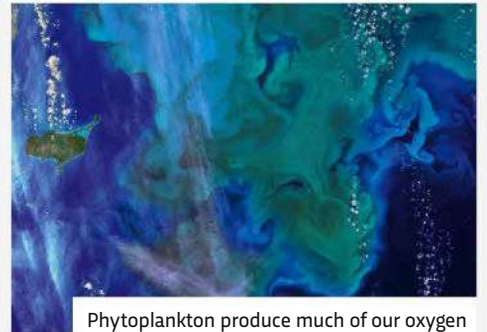
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YOUR FACTS OF THE MONTH

We asked you to send in your favourite recently discovered science facts – and you didn't disappoint...

The majority of our oxygen comes from oceans! Plankton, algae, seaweed and some bacteria photosynthesise and produce roughly half the world's supply.

Brendan Falvey (@BrendanFalvey)



Phytoplankton produce much of our oxygen

Dark energy could eventually make the Universe so large that all of the galaxies in the night sky will have accelerated beyond our horizon – we won't really be able to see them. And, because our knowledge of the Big Bang comes from these galaxies, future scientists could be left in the dark.

Ahmed Nour (@nourishintheory)



Will galaxies vanish from the night sky?



“IN 2023, JAPANESE SCIENTISTS ANNOUNCED THAT THEY HAD MADE EGGS FROM A MALE MOUSE’S SKIN CELLS AND, USING NORMAL MOUSE SPERM, HAD PRODUCED MOUSE PUPS”

PROF HENRY GREELY, p69



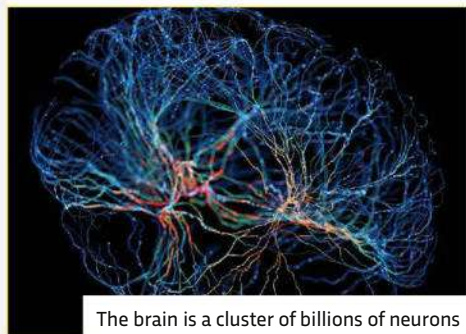
Orbital oopsie

What’s the worst mistake you’ve made at work? It won’t be as bad as this one reported on sciencefocus.com. Two International Space Station astronauts on a spacewalk dropped a reflective tool bag – and it’s now visible from Earth. It’ll stay in orbit for months before burning up in our atmosphere.

Naturally, readers were on hand to offer supportive words to the astronauts via our social media pages. As Lynn (@Scribblynns) pondered: “Will their local hardware store deliver replacements?” Meanwhile, a perplexed Rowan Fawdon asked: “Why wasn’t it attached to one of them, like a child’s mittens on a string?”

There are more stars in the observable Universe (probably at least 10^{22} , or 10 followed by 22 zeros) than there are grains of sand on all of the beaches on Earth! Also, each of our brains comprises around 100 billion neurons, each of which has up to 10,000 connections to other neurons!

Ahmed Abdullah (@SciAhmed0)



The brain is a cluster of billions of neurons

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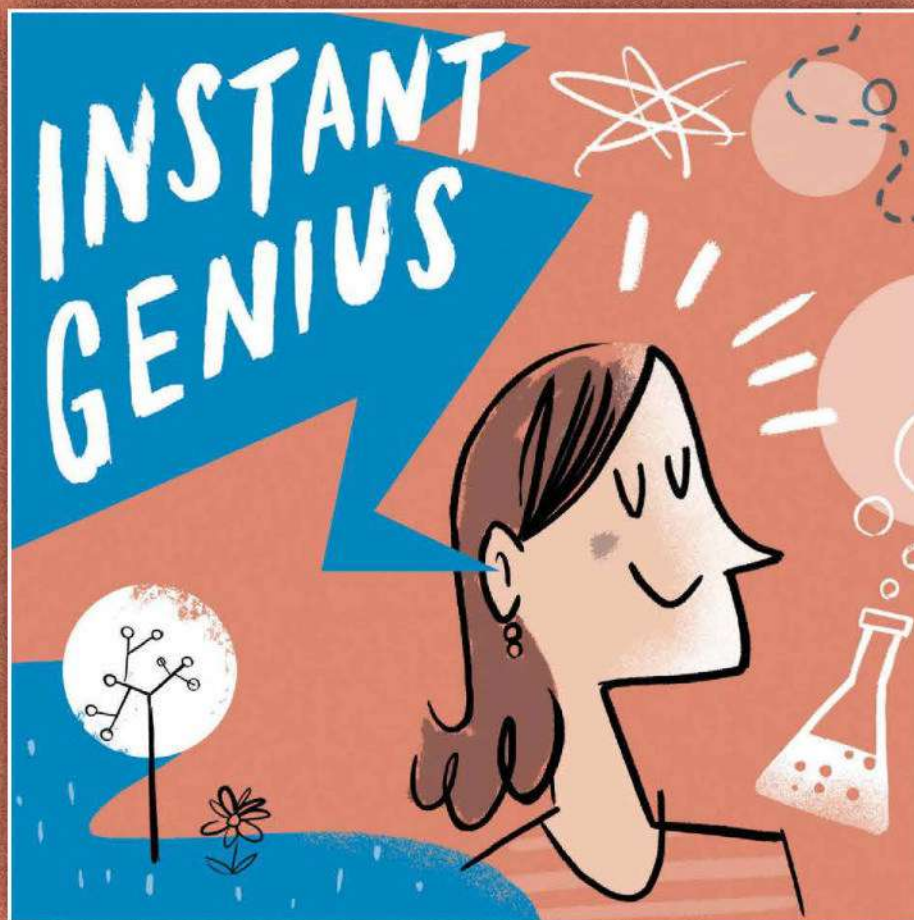
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A recently detected giant planet is upending our ideas about solar system formation

ASTRONOMY

BIZARRE GIANT PLANET COULD REWRITE THE RULES OF SOLAR SYSTEMS

A true giant among dwarfs has been discovered, challenging theories about how planets form

A new paper published in *Science* reveals the discovery of a rare planet seemingly far too big for the star it orbits. The findings challenge everything we know about how planets and solar systems form – as well as how scientists model them.

“An object like the one we discovered is likely extremely rare, so detecting it has been really exciting,” said Megan Delamer, an astronomy graduate student at Penn State, USA, and co-author of the paper. “Our current theories of planet formation have trouble accounting for what we’re seeing.”

The newly identified giant planet is 13 times as massive as Earth, with a similar mass to the ice giant Neptune. What’s strange is that the ultracool star it’s orbiting (named LHS 3154) is nine times less massive than our Sun. That makes the mass

BELOW An artist's impression of the planet so big that it challenges scientists' current thinking, in the foreground, and its star (LHS 3154), in the background



ratio of the planet to its star more than 100 times that of Earth to the Sun.

The discovery marks the first time that scientists have found such a big planet orbiting such a small star. In fact, ultracool stars are famously the coldest and least massive stars in the Universe.

Existing scientific theories posit that stars form from vast clouds of dust and gas. When that process is finished, the remaining matter in the disc orbiting the star develops into planets. But LHS 3154 doesn’t have enough mass (and not enough matter in its disc) to make a planet as massive as this, according to existing theories – forcing scientists to re-examine their ideas.

In fact, according to the scientists’ calculations, the dust-to-mass and dust-to-gas ratios around the developing star would need to have been



“Star LHS 3154 doesn’t have enough mass to make a planet as massive as this, according to existing theories”

ABOVE The mass ratio of Earth to the Sun is more than 100 times smaller than that of the newly discovered planet to its star

10 times higher than the model shows for the planet to be so massive.

The team discovered the unusual pair of bodies while searching for planets with liquid water on the surface, making them potentially habitable for life.

Such planets are easier to find when they’re orbiting ultracool stars. That’s because they need to be relatively close to their star to be warm enough for any water present to remain liquid. This proximity generates a signal that’s more detectable to the astronomical spectrograph used to search for them.

“Think about it like the star is a campfire,” said Suvrath Mahadevan, Professor of Astronomy and Astrophysics at Penn State and co-author of the paper. “The more the fire cools down, the closer you need to get to that fire to stay warm. The same is true for planets.”

“If a planet has a close enough orbit to its ultracool star, we can detect it by seeing a very subtle change in the colour of the star’s spectra, or light, as it’s tugged on by an orbiting planet,” he added.

MEDICINE

YOUR TASTE BUDS COULD BE ENCOURAGING YOU TO BINGE EAT

New insights into the drivers of appetite could lead to better weight-loss treatments

It's one of life's great struggles: resisting the temptation to eat the entire box of doughnuts all at once. Well, it turns out that the secret to appetite control could lie in your sense of taste. That's according to scientists at the University of California San Francisco, who have discovered that brain cells linked to our taste buds, not our guts, are the first line of defence against binge eating.

This finding could be used to develop weight-loss treatments that work better than semaglutide (a drug marketed as Ozempic or Wegovy).

It's true that activity in your gut plays a key role in suppressing appetite. Experiments with mice suggest that the stomach and intestines send signals to cerebellar granule cells (CGC) in the brain, which can curb your appetite, but only after tens of minutes.

Another group of brain cells – known as prolactin-releasing hormone (PRLH) cells – linked to your taste buds can act in just seconds, however. Stimulated when you sense flavour in your mouth, these cells send two conflicting messages around the brain. One says: "This is good food! Eat more!", while the other says: "Slow down or you're going to be sick!" It's the balance between these messages that determines how strong your munchies are.

It's now hoped that a deeper understanding of this balance, and the interaction between PRLH and CGC cells, could lead to the

development of new weight-loss treatments and drugs.

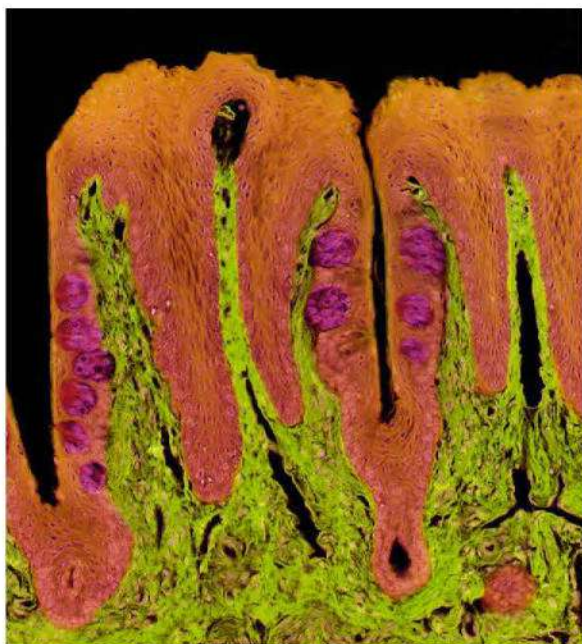
"This discovery gives us a new framework to understand how we control our eating," said Dr Zachary Knight, who led the research team.

"It was a total surprise that [PRLH] cells were activated by the perception of taste," added Dr Truong Ly, the study's lead author. "It shows that there are other components of the appetite-control system that we should be thinking about."

The new imaging technology developed for this research could also be used to better understand well-known weight suppressors such as semaglutide.

"Now we have a way of teasing apart what's happening in the brain that makes these drugs work," Knight said.

Taste buds, coloured pink in this micrograph of a tongue, send conflicting signals to your brain



TECHNOLOGY

NEW NASA AI TOOL SHOWS HOW CLIMATE CHANGE MIGHT AFFECT YOU

The model could help you make important life decisions as the world transforms

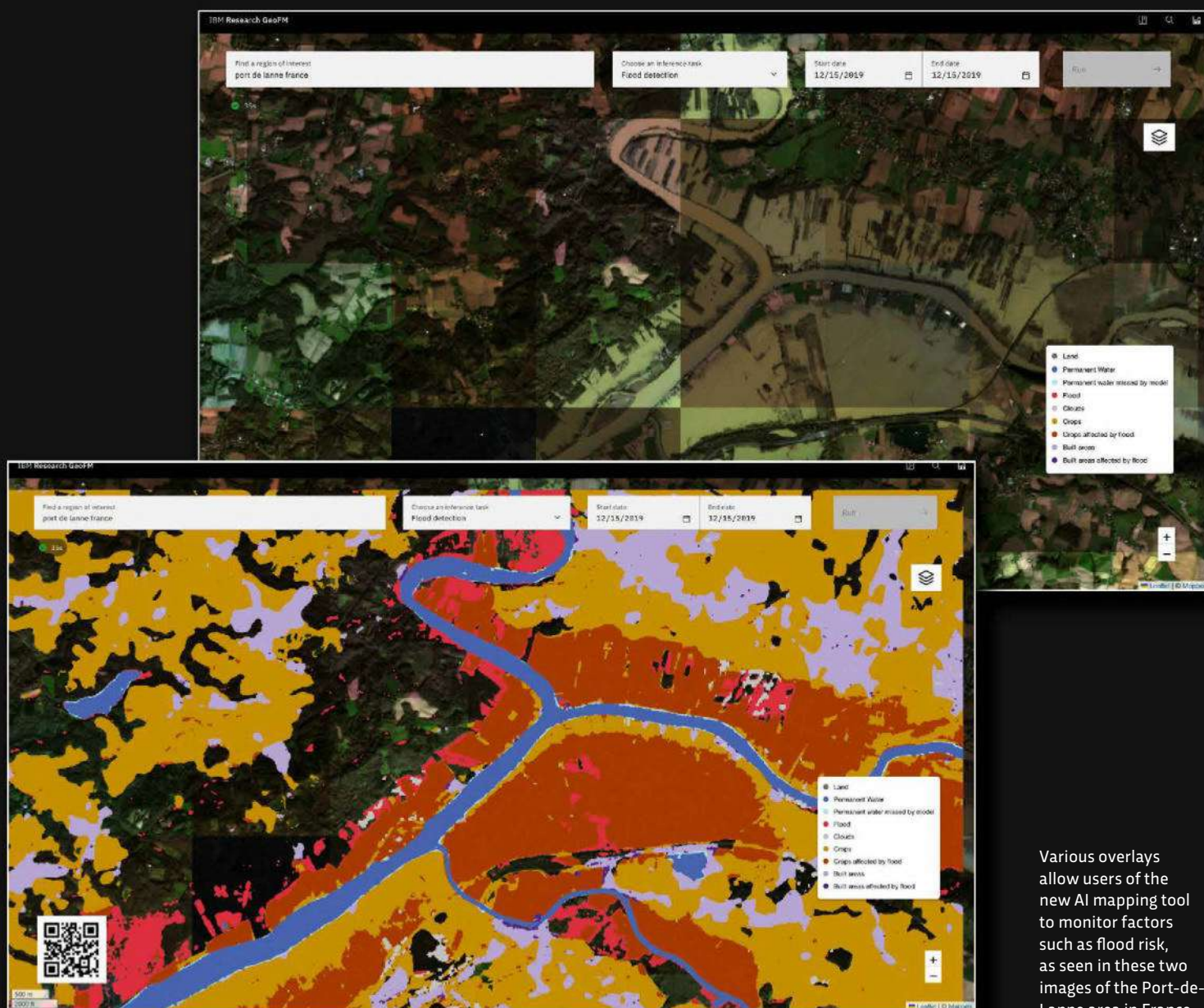
A new artificial intelligence (AI) tool will help us monitor Earth from space – down to street level. Unveiled at the United Nations Climate Change Conference COP28 in November, its developers NASA and IBM say the tool will measure environmental changes that have already happened and make more accurate predictions about the future. The system could help authorities make emergency plans ahead of extreme weather events, such as those that afflicted

“We’ve put the ability to model climate and weather in the hands of the community – and that’s brilliant”

the planet in 2023 and also help us avoid deadly disasters in future.

The tool will resemble the 3D satellite-visualisation computer program Google Earth, although algorithms enable users to toggle between overlays such as tree cover, carbon emissions and risks of flooding or wildfires. And in 2024 it'll be available to everyone: nations, corporations, charities and you.

In theory, you could use it to plan where you should or shouldn't travel, or buy a house, according to Dr Juan Bernabé-Moreno,



Various overlays allow users of the new AI mapping tool to monitor factors such as flood risk, as seen in these two images of the Port-de-Lanne area in France

director of IBM Research Europe for Ireland and the UK.

“The use of the application is really up to the people,” Bernabé-Moreno told *BBC Science Focus*. “Making it open-source means putting it in the hands of the community.”

The tool is an AI-powered foundation model that can map out complex systems using raw data. IBM built it using NASA’s expertise and massive datasets, including information from satellites.

Your trusty old laptop might not be able

to run the new tool, however. According to Bernabé-Moreno, it’s likely to require “a few” graphics processing units (GPUs), components that create complex graphics and visuals. (Many high-performance gaming computers have two GPUs.)

In the future, applying this kind of generative AI to the weather could lead to more accurate forecasts and enable us to better predict hurricanes, droughts and other extreme events. This could help us understand exactly how the effects of climate change – such as large-scale

polar ice melt – might impact our lives.

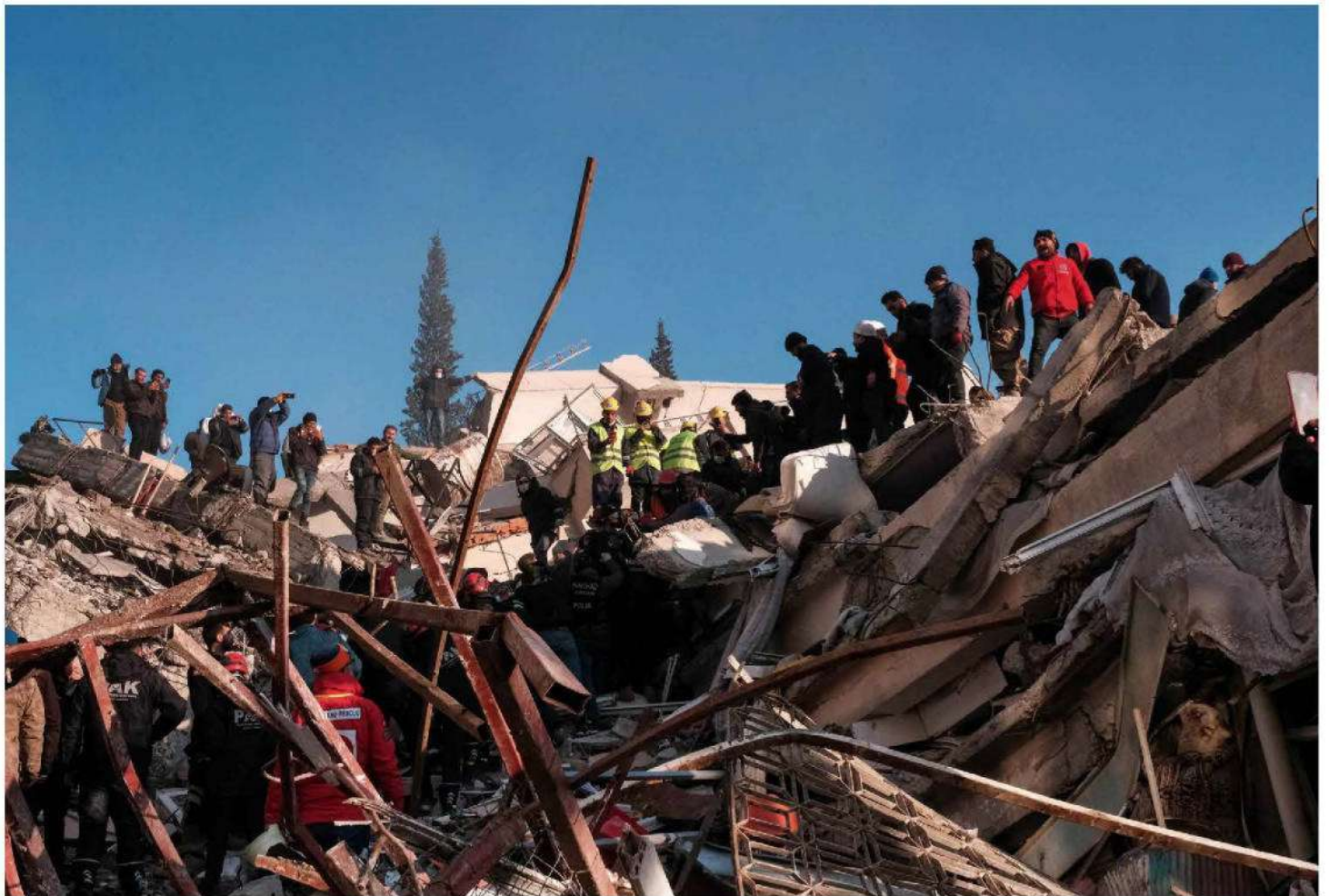
The tool could also enable communities to monitor how well governments fulfil their promises, Bernabé-Moreno said. In fact, the government of Kenya has used an early version to track the progress of its reforestation programme, which spans six counties in the west of the country.

This is part of what Bernabé-Moreno calls the “democratisation of weather and climate”: “We’ve put the ability to model climate and weather in the hands of the community, and that’s brilliant.”

GEOLOGY

HIDDEN SIGNALS UNDER EARTH'S CRUST COULD HELP US PREDICT FUTURE QUAKES

Scientists say that, with the right forecasting, we could track major earthquakes years in advance



Major earthquakes could be predicted months or even years before they strike by detecting unique seismic signals, according to new research from a team of German scientists.

The research, published in *Nature Communications*, suggests that, for more accurate earthquake warning systems, we need more local and regional sites to detect underground signals. It also advises that monitoring secondary faults after a primary fault ruptures could further increase the accuracy of readings.

The team studied data relating to the Kahramanmaraş earthquake that hit Turkey in early 2023, and found that there was an acceleration in seismic event rates and larger energy release roughly eight months before the tremor.

These signals were detected in clusters within 65km (40 miles) of the epicentre. Although the main rupture occurred on a fault line and in an area known to be at risk of earthquakes, signals prior to the event were detected on both main and secondary faults, which hadn't received much attention from scientists.

“Long-term monitoring is crucial to help build our understanding of earthquakes and predict events”

BIOLOGY

SCIENTISTS FINALLY WORK OUT WHAT CAUSES UNUSUAL ITCHING

And it's worse than you think



A 7.5-magnitude earthquake hit the Turkish city of Kahramanmaraş on 11 February 2023, causing widespread destruction and over 40,000 deaths

Some larger earthquakes are preceded by a 'preparation phase', during which signals may be detected. However, the research team noted that such monitoring can be challenging, with so many variables to observe at the same time.

Currently, short-term prediction of earthquake magnitude, time and location is impossible. The scientists behind this new study argue that long-term monitoring is crucial to help build our understanding of earthquakes and predict future events.

Not everyone agrees on how useful this work could be, though. "While this is interesting from a scientific viewpoint, it's unlikely that knowing a big earthquake *might* be on the way within months or years really gets us any further forward in preparing for them," Bill McGuire, Professor of Geophysical and Climate Hazards at UCL, told *BBC Science Focus*.

"The only useful prediction of future seismic activity is arguably the one that accurately fixes the location of a coming quake and its timing to within a few weeks, so as to allow evacuation," he added. "In terms of reducing the impacts of a future quake, knowing one is on the way within months to years wouldn't provide us with the time we would need to retrofit poorly constructed buildings."

Right now, somewhere on your body, you've probably got an itch caused by nothing in particular...

or so it seems. Because scientists at Harvard Medical School in the US have discovered the cause: bacteria living in your skin.

A new paper published in the journal *Cell* reveals that *Staphylococcus aureus* (seen below) releases a chemical that activates a protein in our nerves. This sends a signal from our skin to our brain, which perceives it as an itch.

Plenty of good bacteria live in your skin. This amazing organ is kept healthy by a diverse population of microorganisms. But when that mix of microbes becomes unbalanced, *S. aureus* can run rampant.

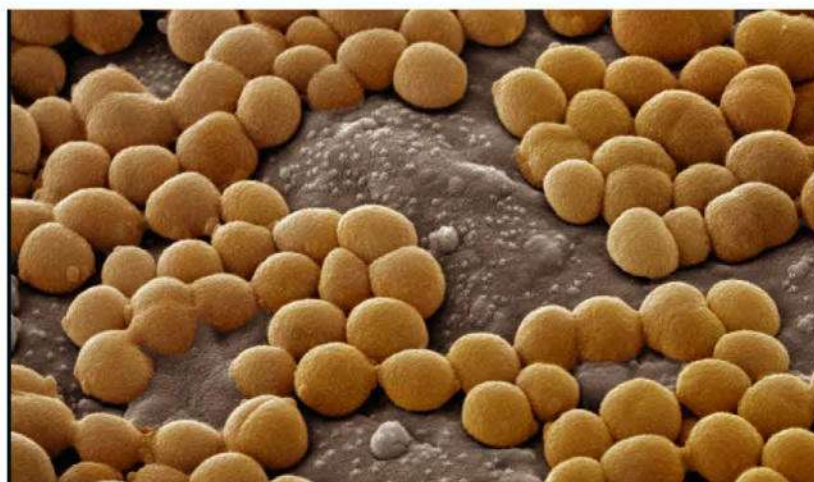
The paper's authors studied both mice and humans. Mice whose skin was exposed to *S. aureus* developed intense itches where the bacteria grew, but also in response to light touches with other stimuli.

The scientists then isolated V8 protease, an enzyme released by *S. aureus* in contact with skin. They tested it on mice and measured levels in human patients' skin. The



scientists concluded that V8 protease is the culprit of itches, stimulating a protein called PAR1 in nerves, which sends an 'itch' signal to the brain. Higher levels of this enzyme were detected in patients with dermatitis than in people with healthy skin.

But how do itches benefit bacteria? "It's speculation at this point, but the itch-scratch cycle could... enable [the bacteria to] spread to distant body sites and to uninfected hosts," said first author Dr Liwen Deng. "Why do we itch and scratch? Does it help us, or does it help the microbe? That's something that we could follow up."



MEDICINE

YOU'RE MORE LIKELY TO LOSE WEIGHT IF YOUR DOCTOR IS OPTIMISTIC

When it comes to enrolling people in weight-loss programmes, the doctor's sales pitch is key

A new study shows that you're more likely to participate in a weight-loss programme if your doctor is optimistic. The study reveals that more weight gets lost by patients whose doctors present the programmes as positive opportunities and barely mention obesity, than by patients whose doctors discuss the programmes neutrally, or with reference to the negative impacts of obesity (an increased risk of heart attacks, strokes and dementia).

For the study, published in *Annals of Internal Medicine*, researchers at the University of Oxford analysed the language doctors used when offering patients a referral to a 12-week weight-loss programme, then monitored patient participation and weight-loss outcomes.

Patients whose doctors presented the programme as an opportunity, using a 'good news' approach, lost an average of 4.8kg (10.6lbs) after 12 months. Patients whose doctors took a 'bad news' approach lost 2.7kg (6lbs), while patients whose doctors were neutral and made neither positive nor negative comments about obesity treatment, lost an average of just 1.2kg (2.6lbs).

The researchers concluded that higher enrolment in the weight-loss programme due to the 'good news' approach taken by optimistic doctors was behind the greater weight loss. That's because 87 per cent of patients with positive doctors enrolled, compared to less than half of the patients with neutral or pessimistic doctors.



Doctors who take a positive approach to weight-loss programmes have a better record of enrolling patients in them

ASTRONOMY

MODELLING COMET IMPACTS COULD HELP US LOCATE LIFE ON OTHER PLANETS

Cosmic snowballs in space may have delivered life-giving molecules to Earth



“Circumstances have to be just right for these molecules to reach a planet’s surface”

A long-held scientific theory proposes that comets deposited the essential molecules for life on Earth to begin. Researchers at the University of Cambridge’s Institute of Astronomy suggest that the same concept could help us pinpoint other planets where life might also evolve.

“It’s an exciting time, being able to combine advances in astronomy and chemistry to study some of the most fundamental questions of all,” said Richard Anslow, first author of the paper, published in *Proceedings of the Royal Society A*.

Comets contain a range of prebiotic molecules, such as amino acids and vitamin B3, as well as hydrogen cyanide. These can combine to form proteins and other molecules involved in the evolution of complex life. But circumstances have to be just right for these molecules to reach a planet’s surface.

Using modelling techniques, the researchers found that planets needed to have a low mass if they’re orbiting

a star similar to our Sun for comets to safely deliver their cargo, as this makes it easier for comets to survive entry into their atmospheres. The researchers also found that comets need to be travelling slower than 15km/s (9 miles per second) when they hit the surface, otherwise the impact, and the high temperatures produced by it, would destroy the prebiotic molecules.

In solar systems containing stars with masses lower than our Sun, where the orbital speeds of the planets are higher, the planets’ proximities may be sufficient to slow a comet enough to enable the safe delivery of potentially life-sparking molecules.

How? By ‘bouncing’ the comet between the planets’ orbits. The comet is pulled in by the gravitational force of one planet, then passed to another. With sufficient ‘bounces’, the comet may slow enough for the prebiotic molecules to reach a planet’s surface intact.

The researchers suggest that scientists looking for signs of the origins of life should focus on such systems.

FUTURE

THE SCIENCE TO WATCH IN 2024

If 2023 is anything to go by, the year to come will witness breakthroughs across every field of science. From cutting-edge advances in artificial intelligence to revolutionary discoveries in health and space exploration, here's what to expect...

Looking up

If all goes to plan, 2024 will see humanity return to the Moon for the first time in 50 years. NASA's Artemis II mission is scheduled to launch in late 2024, carrying a crew of four (left), including the first woman and first person of colour to join a lunar mission.

NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite mission should launch at the beginning of the year, collecting data to help scientists measure the health of Earth's oceans.

The long-delayed debut of Ariane 6, ESA's heavy-lift rocket, is pencilled in for mid-2024. In October, NASA's Europa Clipper will begin its journey to one of Jupiter's icy moons to investigate the possibility of life. And, the Jupiter Icy Moons Explorer (JUICE) spacecraft, launched by ESA in 2023 with a similar mission, will make its first lunar-Earth flyby in August.

And on 8 April a total solar eclipse will sweep across Mexico, Canada and the US – the last to be seen in the contiguous US until 2044.





New frontiers in health

Following the attention focused on weight-loss drug semaglutide in 2023, phase 3 trials of a similar antidiabetic, tirzepatide (Mounjaro), are expected to produce results towards the end of 2024.

Advances in CRISPR therapy are also anticipated after the gene-editing tool received UK approval in November 2023 for the treatment of sickle cell disease and the blood disorder Beta-thalassaemia. US approval is expected by March 2024.

Transplant medicine looks set to reach new heights, too. Biotech company eGenesis has suggested that this year it could provide gene-edited pig organs for human babies in need of transplants.

We should also see the results of clinical trials investigating how AI could improve cancer diagnoses, test the efficacy of new cancer treatments and medication combinations, and trial vaccines against HIV and malaria.

Tech horizons

Speculations about OpenAI's next projects abound, and – although nothing has been formally announced – we'll be expecting updates to its Generative Pre-trained Transformer (GPT) models. Generative AI will continue to find novel applications in research fields and daily life, too.

The future of VR and gaming looks intriguing, as tech giants pour resources into mixed reality.

This year's advances in fundamental areas of human life, from medicine to infrastructure, will be matched and augmented by breakthroughs in robotics, smart materials and eco-materials. We anticipate more advanced robots able to perform micro-operations inside the body, buildings that react to changing weather conditions, and improved solar cells. Some of these may be made with 4D printers, which use smart-materials to create objects that can change shape.



GETTY IMAGES X4, ALAMY, NASA/KSC X2

SCIENCE IN CULTURE



SCI-FI SPECTACLES

Film in 2024 will be dominated by book adaptations, reboots and sequels, from *Spaceman* to *Ghostbusters: Frozen Empire*. It's the sequels that really caught our eye. *Inside Out 2* promises to tackle mental health in teenagers, the first installment having explored kids' minds. And we'll be returning to questions of extraterrestrial terraforming in *Dune: Part Two*.

AI EYES

Artificial intelligence (AI) will supercharge camera operations during the Paris 2024 Summer Olympics. Facial recognition is prohibited, but AI surveillance will help detect abandoned items and suspicious activity in large crowds.



ARTIFICIAL POLITICS

In 2023, OpenAI CEO Sam Altman warned US Congress about the risks AI poses to politics, and with political deepfakes on the rise, concerns about generative AI's capacity for creating mistruths are growing. Still, several significant elections will be held in 2024, including for the US presidency.

COMMENT

UNDERSTANDING MATTER COULD REVEAL THE REASON WE, AND THE UNIVERSE, EXIST

Many questions remain unanswered when it comes to matter, but the biggest one is: Why is there any matter to begin with?

Back in September, researchers at CERN managed to create and capture a sample of antihydrogen (the antimatter version of hydrogen). They held the sample in a magnetic field so precarious that any slight misalignment would cause it to annihilate against the walls of its container. And then they dropped it.

The ALPHA-g experiment was designed to answer the question of just how ‘anti’ antimatter really is. Since antimatter was first proposed in the 1920s, we’ve learned to produce it in experiments and seen evidence for it in high-energy astrophysical environments in space. And we’ve seen that any contact between a particle of antimatter and its regular-matter counterpart results in annihilation into high-energy radiation.

Despite its violent tendencies, antimatter has generally shown itself to be far less outlandish than its reputation suggests. As far as we can tell, an anti-electron (a positron) is exactly like an electron, except it has the opposite charge (+1 instead of -1), and is opposite in ‘parity’ (like a mirror reflection).

Like other versions of antimatter, the mass of a positron exactly matches that of its regular-matter counterpart. But until ALPHA-g, physicists had yet to experimentally confirm that antimatter’s mass acts the same as that of ordinary matter.

Could antimatter have some kind of anti-gravity, too? Does antihydrogen (a positron bound to an antiproton) fall up, instead of down, when dropped?

Alas, the ALPHA-g experiment showed that antimatter does, in fact, fall down. As far as gravity is concerned, antimatter is, really, just matter. But that might lead one to ask: what is matter, really?

What counts as matter in physics depends on the context of the question. The simplest definition of

matter is anything that has a rest mass: a mass that is inherent to the particle and exists when it’s at rest (as opposed to an ‘effective’ mass, which depends on its motion). Atoms, molecules, liquids, solids, gases – all of these are matter, as are the protons, neutrons and electrons that make them up.

But what about massless elementary particles, like photons, gluons or the hypothetical graviton? Even though we classify them as particles, they wouldn’t count as matter in this context.

Weirdly, however, things that are definitely not matter, can contribute to something’s mass. In Einstein’s General Relativity, the gravitational effect of an object is due not just to its matter, but to its energy as well. In principle, a hot bowling ball should weigh more than an identical cold one, because the heat energy adds to its gravitational effect.

Similarly, an atom or molecule is a tiny bit heavier than its constituent particles due to the binding energy of the electromagnetic forces holding it together, even though the electromagnetic field can be said to be made of photons that don’t have rest masses and therefore aren’t considered matter.

When it comes to protons and neutrons, only a fraction of their mass comes from their matter components (the quarks). The rest comes from various kinds of energy involved in holding the quarks together.

In another category, there’s what physicists refer to as ‘exotic matter’, which broadly includes any substance that’s still hypothetical or has properties at odds with what we think of as the rules of the Universe.

Dark matter – invisible stuff that we think is made of an as-yet undiscovered particle – could be called exotic matter, but in a sense, it seems to be fairly ordinary as far as matter is concerned.

It acts just like regular matter, but doesn’t interact with light. For some truly exotic matter, we could look to hypothetical substances like negative-mass matter, which probably doesn’t exist, but could potentially hold up stable wormholes if it did.

Whatever we call the matter we have, we seem to be lucky that it exists at all. Our best theories of particle physics and the Big Bang seem to suggest that matter and antimatter should have come into existence in the cosmos in equal amounts.

That would have been very bad for all involved, because everything would have been annihilated completely into radiation.

For reasons we can’t fully explain, there seems to have been a slight imbalance, allowing all the antimatter to annihilate away while leaving some regular matter to become the stars, galaxies, planets, and people we see today.

Antimatter experiments like ALPHA-g might give us more insights into not just the nature of matter, but also why any of us exist at all. That’s worth dropping everything for.



DR KATIE MACK

(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

“Whatever we call the matter we have, we seem to be lucky that it exists at all”

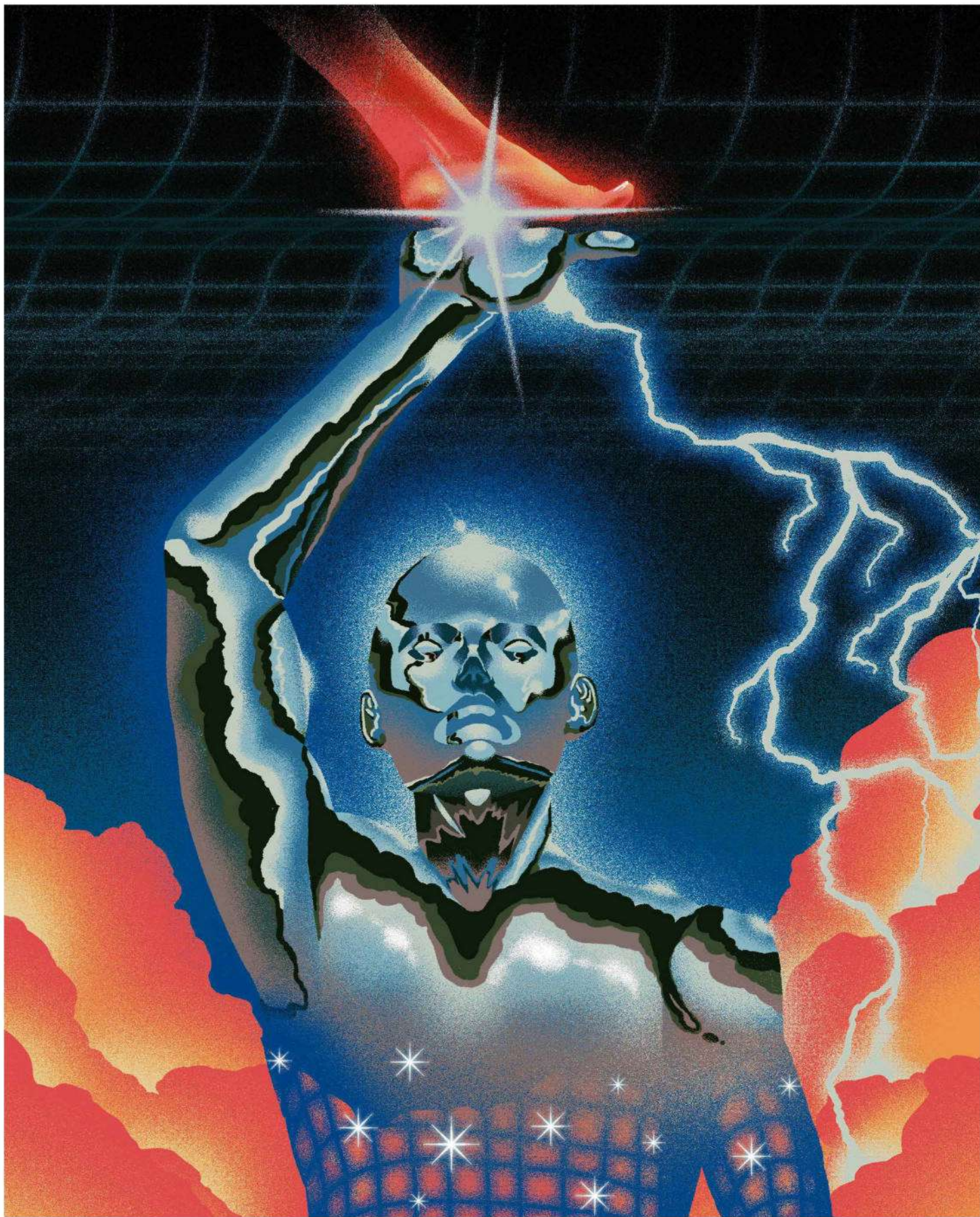


ILLUSTRATION: BERNARD LEONARDO



COMMENT

CLAIMING THE MORAL HIGH GROUND DOESN'T NECESSARILY MAKE YOU GOOD

Subconscious processes in the brain can convince us we're being good, even when we're not

Here's something that's surprisingly common: people who strongly espouse moral or noble ideals, but regularly use them to justify attacking and mistreating others – something which is surely neither moral nor noble.

Isn't this inconsistent? How can someone loudly insist they're a good person while behaving in ways that totally contradict this, without mentally short-circuiting in some way?

The answer is that there are many psychological and neurological processes that allow people to engage in this behaviour that, for want of a better label, we'll call 'virtue bullying'.

A lot of virtue bullying could be seen as virtual bullying, which is to say it's a lot easier online.

We've all seen Facebook posts that make some simple, morally solid claim, such as "Cancer is bad", or "I support victims of [latest disaster]", which are then followed by something like "Share if you agree. I bet 97 per cent of you won't."

Such posts are basically saying, "I'm a good, moral person... and I'll manipulate you and malign your character until you agree." This isn't the behaviour of a good person.

But it's not internet-specific. Wanting to protect children is a good, moral aim, but consider all the books and shows banned or attacked in the US under the guise of protecting children.

Indeed, the many atrocities committed in the name of a 'kind, benevolent' God or religion means history is awash with self-described good, moral people doing very bad things.

Good people treating others badly makes more sense when you realise there are several unconscious processes happening in our brains that help convince us we're 'good', even if we're not.

There's the fading affect bias, which leads to memories linked to negative emotions being forgotten more easily; hindsight bias, which causes us to convince ourselves that a past event was inevitable; impression management, a phenomenon that leads to our brains constantly exaggerating our best qualities, and many others.

As one 2014 study found, our brains work hard to preserve, and enhance, our self-esteem. But self-esteem is heavily influenced by other people and our relative social 'status'. We want to be liked and hate rejection. A 2011 study found that an effective way to boost our self-esteem is to attack or demean others, so our status becomes (relatively) higher.



“History is awash with self-described good, moral people doing very bad things”

So, thinking you're good while attacking others can be a very instinctive process, sadly.

For humans, our morals are a key aspect of our self-image and self-worth. Indeed, research has shown that our morals are a key part of our identity, and an important facet in our motivation and decision-making.

We're innately protective of our identities and decision-making. If these things are underpinned by morals and beliefs, we'll be subconsciously wary, and hostile, to anyone who poses a threat to them.

This can lead to what seems to be inconsistent behaviours. People may consciously think moral things like “Being kind and good to others is important”, but their subconscious says, “And anyone who disagrees is a viable target.” Hence, we get virtue bullying.

Human brains are also hard-wired to crave fairness and justice. These have a strong subjective component, however. Meaning, our understanding of fairness and justice, and our morals, are heavily influenced by

experience. The world around us, and the people we relate to, shape our morals and understanding.

Humans are weird, because we'll readily endure personal loss if it means justice is done. So, doing objectively immoral things, to those you deem immoral, in the name of your morals is, while confusing, far more common than you'd expect.

Striving to be good should be lauded and encouraged. Especially because the human brain is still running on millions-of-years-old programming that gifts us with many subconscious hostilities and prejudices. It requires constant vigilance and effort to stick to your moral values in the face of your 'baser' instincts. And it's only human to slip up.

But when you do, you end up thinking “I'm a good person, but I did something bad”. This can lead to the psychological discomfort known as cognitive dissonance, where your actions and thinking don't match up.

One way to resolve this is to think “I behaved badly, but to someone who is morally wrong, so it's okay.” In reality, nothing's ever that simple. But it's an easy fix for dissonance and allows you to virtue bully to your heart's content.

Ultimately, for all the explanations offered here, it really should be acknowledged that some people are just... not nice. To the extent that they'd use some morally praiseworthy goal or belief as a fig leaf to disguise cruel and bullying tendencies. How you deal with such people is up to you. Who am I to judge?



**DR DEAN
BURNETT**

Dean is a neuroscientist and author. His latest book, Emotional Ignorance, is out now. (£14.99, Guardian Faber).



COMMENT

WE'VE NEVER TAKEN WOMEN'S HEALTHCARE SERIOUSLY. IT'S ABOUT TIME WE DID

How much pain is 'normal' for a person to have to endure?
For women, that normal is often more than for a man

There's a flaw in the healthcare system and it's having dire consequences for women. It's the fact that pain in women is more poorly understood, compared to pain in men and is thus mistreated.

It's known as the gender pain gap, and it's widening. A recent report by Nurofen showed that in 2023, 11 per cent more women than men felt their pain had been ignored or dismissed, compared to 7 per cent in 2022.

The report surveyed more than 5,000 people, with a near 50:50 split between men and women. It found that it takes UK women longer than men to receive a medical diagnosis for the same types of pain. 47 per cent of women surveyed received a diagnosis within 11 months, compared to 66 per cent of men.

Additionally, more women than men (14 per cent vs 9 per cent) still didn't have a diagnosis for their pain after 12 months or longer. And a third of women felt the delay in diagnosis was because they were not listened

Women are waiting longer to get a diagnosis for their pain, and don't feel empowered to push for the support they need. This is unacceptable."

Often, we hear that women are told their pain 'is normal for a woman'. The issue here is that 'normal' makes the woman feel it's acceptable to have and feel the pain, and that there's nothing wrong. Therefore there's nothing to be done about it, nor scope to improve it.

But in fact, instead of normal, healthcare professionals mean one or more of the following: 'this pain is common', 'we expect this to happen' or 'we know this happens and you're not alone'. But this is often not communicated, with 'normal' being the default.

This is damaging to the patient's confidence and empowerment, so advocacy is broken, which affects the remainder of that consultation, and any further ones.

Women live longer than men, but a greater proportion of their life is spent in ill health, therefore they have a lower healthy life expectancy. It's likely that the gender pain gap is a factor in this, especially as more women than men suffer from chronic conditions.

The gender pain gap is obviously complex, but its existence isn't surprising, given that it was only in 1993 that the Food and Drug Administration in the US finally permitted women to participate in clinical trials. Up until then, medical observation and intervention at a clinical standard wasn't carried out in females, leading to a massive gap in the understanding of women's healthcare.

This has resulted in a 'male as default' in medicine, research and clinical trials, which means less is known about pain conditions that predominantly affect women, or about how conditions affect men and women differently.

Then there's the fact that women's health research funding is disproportionately low, given that around 50 per cent of the population is female. Frustratingly, research findings are also rarely disaggregated by sex, thus missing the chance to significantly increase our knowledge across many fields of science and healthcare in regard to women.

The gender pain gap isn't just studies and statistics, though; it's blighting women's lives.

Take Chloe, someone involved in the Nurofen report. She had periods so painful she would 'collapse, faint and throw up'. When it became daily pain, it was misdiagnosed as a urinary tract infection or dismissed as 'seeking attention'. As is common for many in this situation, Chloe felt alone, dismissed and started to question her own mind. She was finally diagnosed, seven years on, with Stage 2 endometriosis affecting her womb and pelvis.

Women are struggling to have their pain taken seriously and properly treated in a healthcare system that underserves and overlooks them. It's exacerbating health inequality, as women accept more pain, avoid seeking advice, and delay treatment for it. It is having a significant impact on every aspect of their lives. It is unfair and unnecessary. And it must stop.

"Less is known about pain conditions that predominantly affect women"



DR MICHELLE GRIFFIN

Michelle is the director of MFG Health Consulting, as well as a women's health expert and strategy advisor in women's health tech.

to, or taken seriously by their healthcare professionals, or, worse still, completely dismissed.

Similarly, in a survey of over 110,000 women taken in 2021 for the Government's Women's Health Strategy, 50 per cent of women felt their pain was ignored and/or dismissed. This dismissal was often coupled with being told that certain symptoms should be accepted as inherent to being a woman, and therefore didn't require treatment. This was particularly prevalent in relation to menstrual health.

Dr Marieke Bigg, sociologist and author of *This Won't Hurt: How Medicine Fails Women* says: "... healthcare professionals continually misattribute women's symptoms to stress or 'hormones', while men are more likely to be sent for a physical check – even when complaining of the same type of pain. Over time, this has led to women's pain being overlooked, resulting in a gender pain gap.

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

Volcanic eruptions | Cat coronavirus | Wooden satellites



REVIEW

VOLCANIC ERUPTIONS: A NUMBER OF VOLCANOES ARE ACTIVE NOW. IS IT A SIGN OF TROUBLE?

With volcanic activity being reported everywhere from Iceland to Italy, should we be concerned that a catastrophic event is looming?



“These tectonic plates are moving apart at about the same rate as your fingernails grow, allowing new magma to rise and feed eruptions”



For more fact-checking news, visit the BBC's Verify website at [bit.ly/BBCVerify](https://www.bbc.com/news/verify)

Back in November, thousands of small earthquakes rocked southwest Iceland as magma rose towards the surface along a 14km (8.5-mile) fracture near the Svartsengi geothermal power plant. Molten rock opened wide fractures that sliced through the small town of Grindavík. The ground continued to swell and, at the time of writing, an eruption remains possible.

At around the same time, Mount Etna on the Italian island of Sicily exploded, dumping ash on nearby towns.

That's not all. Across the world, 45 other volcanoes continued to rumble, including Mayon and Taal in the Philippines, Santa María in Guatemala, Nevado del Ruiz in Colombia and Anak Krakatau in Indonesia. That last volcano is rising again following a major collapse in 2018, when it created a tsunami that killed more than 400 people.

HOW ACTIVE ARE THESE VOLCANOES?

It's possible that the magma rising near Svartsengi may not erupt at all, but instead will solidify beneath the surface. If it does reach the surface, though, it's likely to be in typically Icelandic style: very fluid lava will pour out of long cracks, occasionally solidifying into spectacular cones.

The recent eruption of Mount Etna marks business as usual at a volcano that's always sparking minor firework-like displays, pumping out lava or launching columns of ash high into the atmosphere.

Activity at the rest of the world's currently active volcanoes is – for the time being, at least – relatively inconsequential, involving minor explosions, lava outbursts or the formation of small pyroclastic flows (rapidly moving flows of hot ash and gas). Only people living on or close to the volcanoes face a real threat, and exclusion zones have been put in place in those spots in case activity escalates.

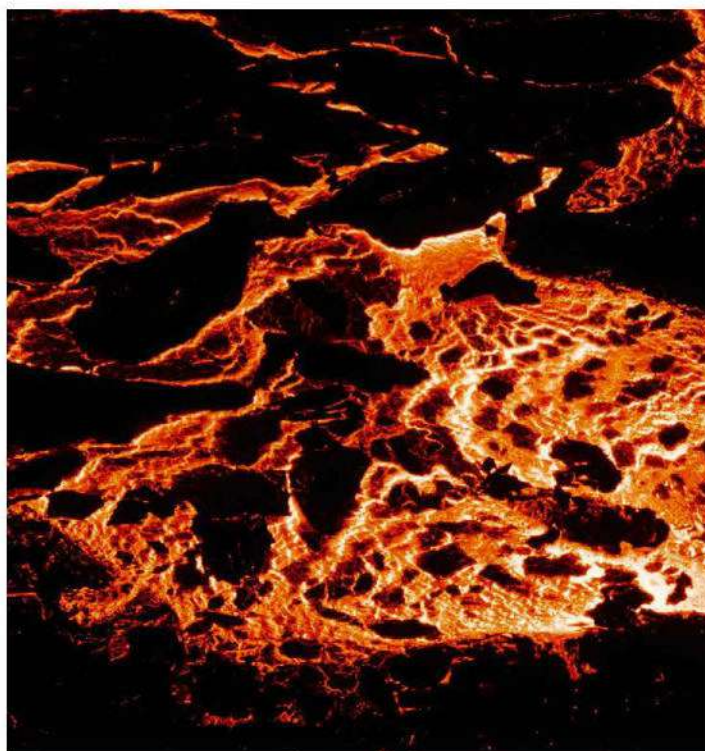
WHY ARE ALL THESE VOLCANOES ERUPTING?

Volcanoes erupt when fresh magma produced in the Earth's mantle reaches the surface, either via an open vent or by breaking through the rock above it.

This actually happens all the time. About 70 volcanoes erupt every year, with around 20 erupting on any one day. Iceland alone has an estimated 30 volcanic systems – discrete zones where eruptions can occur, either from an established cone or from new fissures (cracks in Earth's surface). In fact, Iceland, which straddles the line where the North American Plate to the west meets the Eurasian Plate to the east, is built entirely from volcanic rock. These tectonic plates are moving apart at about the same rate as your fingernails grow, allowing new magma to rise and feed eruptions, which happen somewhere on the island every few years.

Elsewhere, many of the currently active volcanoes around the world are located above so-called subduction zones, where one tectonic plate is forcing its way beneath another. As a subducting plate pushes further down into Earth's mantle it begins to melt, sweating out magma that feeds the volcanoes above. Typically, these magmas are stickier and more gas-rich than those emerging in Iceland – and they can feed far bigger, deadlier explosive eruptions. →

BELOW Shield volcanoes produce fluid lava that flows from cracks in the surface of their shallow sides





ABOVE Iceland's Fagradalsfjall volcano erupted in 2021 and 2022. At the time of going to press, Iceland's Met Office was warning another eruption could be imminent

→ HAS VOLCANIC ACTIVITY LIKE THIS EVER HAPPENED BEFORE?

In 2021, Iceland's Fagradalsfjall volcano erupted after a long period of dormancy, putting on a spectacular show just 40km (25 miles) southwest of Reykjavík. That was the first time in eight centuries that an eruption had occurred on the Reykjanes Peninsula, but the region may now experience new eruptions for decades to come.

Etna, on the other hand, is never quiet, but its past activity has been far more destructive. The main problem has come from lava outbursts on its lower slopes, which caused considerable damage to inhabited areas in 1928, 1971 and 1983. An enormous lava eruption in 1669 destroyed parts of the coastal city of Catania.

Many volcanoes displaying low-level activity have produced bigger eruptions in the past. In 1883, a colossal explosion of Krakatau ('mother' of Anak Krakatau) killed 36,000 people. When Nevado del Ruiz erupted in 1985, some 23,000 lost their lives. And in 1902, Santa María produced one of the biggest volcanic blasts of the 20th century, killing around 6,000 people.

SHOULD WE BE WORRIED ABOUT ERUPTIONS?

The short answer is: no more than usual – unless you live in Grindavík. Its citizens were evacuated in November.

A small concern is that a future Icelandic eruption might follow the same pattern as the Laki event of 1783, when a voluminous outpouring of lava was accompanied by a huge volume of poisonous gas. A noxious cloud spread to Europe and eastern North America, polluting the air, sparking extreme weather and causing famine as far afield as Egypt and perhaps India.

Elsewhere, nothing significant is on the cards, but one thing I've learned in four decades of studying volcanoes is to always expect the unexpected.

by **PROF BILL MCGUIRE**

Bill is Professor Emeritus of Geophysical and Climate Hazards at UCL, and author of Hothouse Earth (Icon Books, £9.99).

ANALYSIS

CAT CORONAVIRUS: A NEW VARIANT IS SPREADING IN CYPRUS

The new strain has killed thousands of felines on the island and at least one cat in the UK has been infected

You may have heard reports of a cat in the UK having been infected with a new coronavirus strain responsible for thousands of cat deaths in Cyprus.

Estimates of the number of cat deaths caused by this new virus range from about 8,000 to more than 300,000. In other words, it could be a real cause for concern.

Following the events of the past few years, we're all too aware of the threat a new coronavirus strain can pose to humans – and it's no different for other species. This new cat coronavirus strain appears to be both deadly and highly infectious, and could quickly take hold. So are we on the brink of the feline equivalent of the COVID-19 pandemic?

Before drawing parallels between the current outbreak in cats and the COVID-19 pandemic that surged through the human population, it's worth zooming in to understand what has been happening to the virus on a molecular level.

Based on one study (yet to be peer-reviewed), it seems that an existing cat coronavirus has recombined with a dog coronavirus to create a completely new coronavirus. (The SARS-CoV-2 virus behind the pandemic also emerged from a recombination event.)

This recombination has led to a change on the cat coronavirus spike protein, the structure that enables it to enter host cells. This has made the virus not only more infectious, but also potentially able to cause more severe illness – a dangerous combination.

This new virus, designated F-CoV-23, can cause a severe disease called feline infectious peritonitis (FIP). White blood cells become infected, causing symptoms including lethargy, diarrhoea, fluctuating fever, reduced appetite, weight loss and inflammation. Most infected cats will also develop the so-called 'wet' form of FIP. This causes a build-up of fluid inside an animal's body, leading to a swollen abdomen or chest cavity, often resulting in breathing difficulties. Without treatment, FIP is almost always fatal.

Despite this dire prognosis, it's important to be clear that this virus is distinct from SARS-CoV-2. There's also no evidence that it can be transmitted to – or cause disease in – humans.

The good news is that infected cats seem to respond well to veterinary care, though effective treatments

“This coronavirus is not only more infectious, but also potentially able to cause more severe illness”



are expensive. An existing antiviral drug called GS-441524 seems to be safe and effective. In addition, human COVID-19 antivirals such as Remdesivir and Molnupiravir also seem to work in cats, although they aren't currently licensed in the UK for veterinary use in cats.

While recognising that this is a potentially serious situation and that widespread infection could occur, there's no need for panic right now. At the time of writing (late November), there's no confirmation that this virus is present in the UK, beyond the single infected cat that is being treated.

There have been unconfirmed reports of numerous other cats in the UK with links to Cyprus that possibly

ABOVE Many cats in Cyprus, including this one being treated in Nicosia, have developed feline infectious peritonitis, after contracting a new strain of coronavirus

have the disease, however. This is concerning, because these animals could have brought the disease to the UK.

As we know all too well, when it comes to the spread of coronavirus through a population, the situation can change very quickly. And once the virus takes hold, it can be very difficult to turn things around. We don't know what may happen in the weeks to come, but there's a real potential for this disease to spread beyond Cyprus to the UK and other countries across Europe.

If you want to understand how difficult it may be to bring this disease under control once it starts to spread, think about how challenging it was to persuade humans to follow rules introduced to limit the spread →



ABOVE Blood tests can diagnose feline infectious peritonitis, a fatal disease that can be caused by the new coronavirus strain

→ of COVID-19. Add cats into the equation, bearing in mind their unpredictable behaviour – roaming widely and socialising freely – and it's not difficult to see how things could escalate very quickly.

At the moment, we're still in the 'monitor and stay alert' phase. It's not outside the realms of possibility that there are unusual drivers involved in the spread of this disease in Cyprus, with its large and genetically distinct population of feral cats.

It's also possible that this coronavirus may not pose the same sort of threat to cat populations in the UK and other countries that don't have the same number and density of feral cats. Pets are, of course, far more likely than feral cats to be taken to the vet and to receive treatment.

That's not something we should rely on, however, and this is definitely a time when we should implement the precautionary principle. Bolstering the rationale for that approach, reports have emerged that the virus is now circulating in mainland Greece and Lebanon, though numbers of infections or deaths are difficult to determine.

Given these latest developments, calls from several commentators to ban the importation of cats to the UK from countries where this virus is circulating seem reasonable.

If you own a cat in the UK that becomes unwell, and if your cat hasn't recently been to Cyprus or been in contact with a cat from Cyprus, your index of suspicion that it has FIP should be quite low at the moment. In other words, it's very unlikely to be infected with this new coronavirus.

Watch this space closely, though. Once again, we may find ourselves waiting for vaccines to be developed to save us – or, in this case, our cats – from a deadly disease.

by **PROF HASSAN VALLY**

Hassan is an epidemiologist based at Deakin University, Australia, where he investigates responses to disease outbreaks and epidemics.

COMMENT

WOODEN SATELLITES: LIGNOSAT PROJECT MAY REDUCE SPACE JUNK

US and Japanese space agencies are teaming up to launch lumber in an effort to reduce space litter

In 1957, the first human-made object successfully launched into space was placed in orbit around Earth. This was Sputnik 1, a beautifully simple, Soviet-made spherical satellite with just four antennas.

But this historic event also marked another, more unsettling first: humanity had deposited its first piece of space debris. Part of the 267-tonne, 30m-tall rocket that launched Sputnik was stuck in orbit. Suddenly the world had a problem that we didn't know we needed to solve: the littering of outer space.

Thankfully, Sputnik and that rocket remnant de-orbited and burned up in our atmosphere fairly quickly after launch. That hasn't always been the case, however – far from it. Over the course of just 66 years of space exploration, a vast amount of detritus has been left in orbit around Earth.

Now NASA and the Japan Aerospace Exploration Agency (JAXA) have an idea to help solve this issue: satellites made from a widely available, biodegradable material – wood.

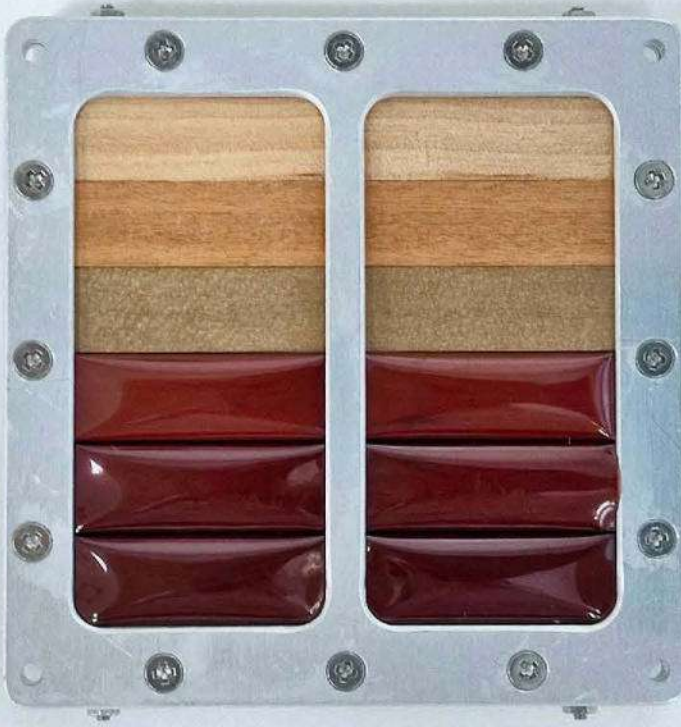
The problem the agencies aim to address is a big and complex one – and finding out just how big was the first stage of the project. We know that at least 130 million pieces of human-made debris orbit Earth, most of them whizzing around at over 7km/s – eight times faster than a typical bullet. Although that's a staggering number, some scientists think it's a conservative estimate.

Most objects sent into space stay there until they either de-orbit and burn up during re-entry, or are moved away from Earth and pulled into a graveyard orbit where they'll circle for hundreds of years. The majority of such objects are actually very small – less than 1cm (0.3in) wide – from chips of paint to small bits of electronics and fragments of insulation foam or aluminium. This tiny debris can't be seen from Earth, even with powerful telescopes. So we must look for the evidence it leaves behind when colliding with other objects in space. This is no easy task.

Work on evaluating the scope of this issue began in earnest after five special objects repeatedly went into orbit and returned home: the NASA Space Shuttles. Between 1981 and 2011, NASA launched 135 shuttle missions. After each shuttle returned to Earth, it was evaluated to identify any damage caused by orbiting debris, enabling NASA to get a clearer picture of the problem of small bits of defunct spacecraft flying through space.

NASA scientists found that small pieces of debris, only millimetres across, could create small, but powerful impacts

× “Another upside to wooden satellites is their reflectivity or, rather, lack of it”



and produced the first estimates of just how bad the debris environment was becoming.

Earlier, in 1978, NASA scientists Don Kessler and Burton Cour-Palais had proposed a scenario named the Kessler Syndrome. The phenomenon they mooted is a catastrophic chain of events triggered by a satellite getting splintered by a piece of space junk. The debris created destroys more satellites, producing yet more junk, and so on, in a never-ending cascade.

Clearly, this is a huge issue. So how do we slow the rate of debris creation, or eliminate it altogether? Solutions proposed include de-orbiting spacecraft within five years of launch, using radiation-hard materials (less susceptible to damage from exposure to high levels of radiation and extreme temperatures) and launching with reusable rockets.

ABOVE

The durability of various types of wood was tested in 2022 on the International Space Station. Magnolia proved most suitable for making satellites

Or we could try wooden satellites. LignoSat, as NASA and JAXA's project is named, is a 10 x 10 x 10cm (4 x 4 x 4in approx) wooden box constructed using traditional Japanese joinery techniques to house electronics and other materials required for a space mission – much like current CubeSats.

Wood samples were tested for suitability on the Japanese Experiment Module Kibo of the International Space Station for over 290 days in 2022. Magnolia performed best, coping well when bombarded with intense cosmic rays and subjected to extreme temperature changes in that harsh environment. It doesn't rot, crack or deform, and has the critical property of burning up into a fine ash when it re-enters the atmosphere, leaving behind little debris.

Another upside to wooden satellites is their reflectivity – or, rather, lack of it. Currently, reflections from aluminium satellites can be extremely bright, spotted easily by the naked eye from Earth. Crucially, this reflected light can reach sensitive areas and interfere with astronomical observations.

The test launch of the LignoSat is currently pencilled in for 2024. If successful, it could pave the way for further missions. So will all satellites be made from wood in the near future? Unfortunately, it's unlikely. Most satellites are privately owned so, unless large companies quickly embrace this new technology, it's unlikely to be widely adopted. In addition, it might not be suitable for certain types of satellites – those carrying sensitive scientific equipment that needs significant radiation shielding, for example.

On the plus side, projects such as this encourage researchers to think outside the box, and could have more impacts down the line. If LignoSat is successful, more research groups may try implementing biodegradable materials in an effort to curb the creation of more debris.

For now, however, we must work to track as many objects in orbit around Earth as possible, to mitigate future collisions with material in space. **SF**

by **DR SARA WEBB**

Sara is an astrophysicist and science communicator based at Swinburne University of Technology in Melbourne, Australia.

THE BEST INNOVATIONS OF 2023

PUSHING TECH BOUNDARIES

The desire to improve things is what drives technological innovation. Here are the game-changing innovations unveiled over the last year that caught our attention for taking improvements to a whole new level



...The ultimate e-bike

For anyone who lives in hilly areas, the rise of e-bikes has been welcome. Gone is the embarrassment of puffing up a climb at a snail's pace, while getting overtaken by walkers. A few companies stood out this year, but our favourite is Cowboy, whose Cruiser is as much computer as mode of transport. It has a built-in phone charger, automatic lights and an app to measure your battery life, speed, location and more. Swapping the chain for a belt and hiding the electrical parts inside the frame ensures a sleek, minimalist design – and makes it nigh impossible to break. There are no gears – instead, the bike automatically provides enough power for any given situation. It's no surprise, then, that this is not a budget e-bike, but it could be worth the outlay all the same.

Cowboy Cruiser

[UK.cowboy.com](https://uk.cowboy.com), From £2,190





...The next-gen AI image generator

ChatGPT was the biggest tech news story of 2023, but its lesser-known sibling, DALL-E, also broke new ground. Launched in early 2021, the original DALL-E was one of the first and most influential artificial intelligence (AI) image generators. With the third iteration unveiled in 2023, OpenAI – the company behind ChatGPT – continued to make the technology more powerful and accurate. For DALL-E 3, detail and understanding of prompts have improved, along with copyright controls (artists can opt out of having their work used for training the AI). Earlier versions were confused by complicated subjects and requests demanding high levels of logic, but DALL-E's 'brain' has also been tweaked to better understand the context of images. We'll be talking about this kind of technology for years to come. Whether that's a good or bad thing remains to be seen.

DALL-E 3

openai.com, Free

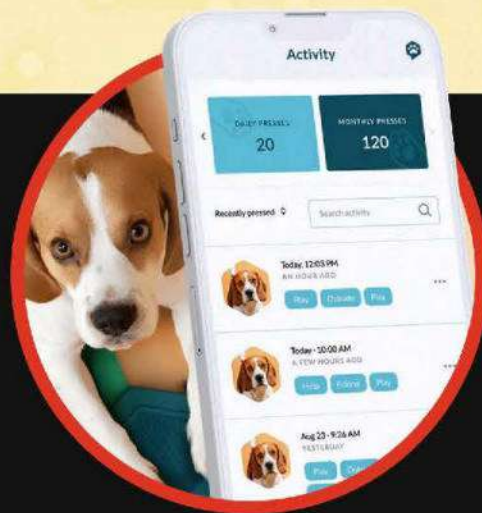


...The perfect folding smartphone

Not too long ago, all smartphones followed the same design formula. Now, besides the familiar simple black slab, smartphones can fold over on themselves, and wrap up and down like roller blinds. However, most of these admittedly impressive designs ignore one key factor: practicality. Not the Samsung Galaxy Z Flip series, however, which hits a happy middle ground – innovative, but not too complicated; high-spec, but not too expensive; fun, but practical. With each new model, Samsung makes the folding aspect more useful, so it's less of a gimmick. The core principle behind the Z Flip5 is to encourage you to look at your smartphone less. When folded, a small display shows important info at a glance, reducing the need to open it at all (but you still get the joy of slamming your phone shut after annoying calls).

Samsung Galaxy Z Flip5

samsung.com, from £1,049

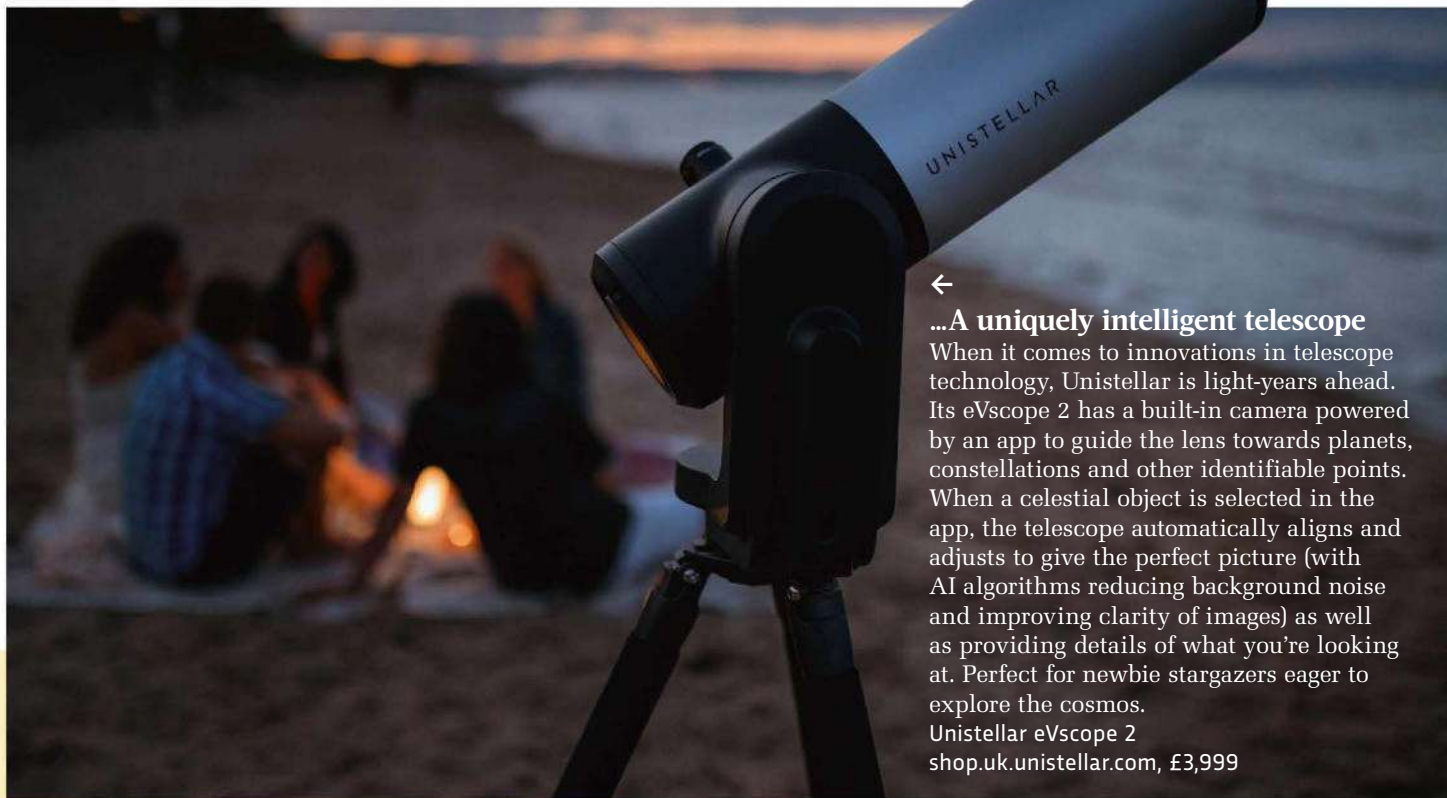


...The pet language tutor

Every pet owner has looked at their cat or dog and thought: "I wish I knew what you're thinking." Well, now you can... kind of. FluentPet makes a collection of buttons, each one playing a different word when pressed by your pet. This, theoretically, enables them to learn to 'talk' with you. Though the animals can't understand the words in the way that humans do, they'll see the actions that follow after they've pressed a particular button. Your pet can thus, so the idea goes, learn to associate that button with, say, 'a walk' or 'food'. Depending on how deep into the world of dog and cat conversations you want to dive, a variety of kits are available.

FluentPet

fluent.pet, from £33



...A uniquely intelligent telescope

When it comes to innovations in telescope technology, Unistellar is light-years ahead. Its eVscope 2 has a built-in camera powered by an app to guide the lens towards planets, constellations and other identifiable points. When a celestial object is selected in the app, the telescope automatically aligns and adjusts to give the perfect picture (with AI algorithms reducing background noise and improving clarity of images) as well as providing details of what you're looking at. Perfect for newbie stargazers eager to explore the cosmos.

Unistellar eVscope 2
shop.uk.unistellar.com, £3,999



...A recorder with model looks

The TP-7 isn't the smartest of gadgets, nor the cheapest – but my, doesn't it look good! Teenage Engineering is all about simplicity, making products that look great and work just as well. There are no bells and whistles on this retro-futuristic-looking device; it just records. With the brushed steel case fitting perfectly in your palm, press the rocker to rewind or fast forward. The spinning disc in the middle is a joyful nod to the tape recorders of yesterday, as are the clickable record, start and stop buttons. Though it's light on features and high on price, the TP-7 is capable of making great-quality recordings even in busy environments, to capture music, interviews or even just passing thoughts. The device pairs with an app on your smartphone to upload audio automatically, ready to be listened to, or transcribed using AI. If it weren't for the seriously hefty price tag, this would be a near-essential purchase. As it is, the TP-7 is a high-functioning object of desire.

Teenage Engineering TP-7
teenage.engineering, £1,299



...Easy-repair headphones

Fairphone has long produced smartphones that are easy to repair, last longer and made with environmentally conscious materials. Now the brand has turned its attention to audio with its Fairbuds XL over-ear headphones, launched with three core aims: to sound great, be sustainable and last as long as possible. Having not actually tested them, we know only that the specs suggest great audio quality – though they're up against some fantastic-sounding headphones at similar prices. But by using recycled materials and offsetting carbon emissions, Fairphone aims to reduce eco-anxiety with these, too. Finally, pretty much every component in them can be repaired at home or replaced easily: you can switch out the battery, install new earcups, replace broken speakers. It's the closest thing you'll find to an immortal pair of headphones.

Fairphone Fairbuds XL
shop.fairphone.com, £219





...A net-zero-carbon shoe

The Allbirds M0.0NSHOT has a light tread – both literally and in terms of its environmental footprint. Claimed to be the world's first net-zero carbon shoe, it comprises a superfine merino wool upper from a net-zero carbon farm in New Zealand, which is paired with a sugarcane-derived foam midsole and bioplastic eyelets. Launching such a groundbreaking product on a large scale is a long-term goal; for now, you can only glimpse M0.0NSHOT at a pop-up in Selfridges London, but it should be available to buy in late 2024.

Allbirds M0.0NSHOT
allbirds.co.uk, £TBC



...A self-ventilating jacket

Say goodbye to sweaty runs and awkward fiddling with zips on the go, and hello to Nike Aerogami technology. Tiny, winged, moisture-reactive vents open as you sweat, improving airflow and keeping you cool and comfortable. Then, once you've been suitably air-cooled, the vents automatically close again. The all-black Nike Running Division Aerogami jacket has the added benefit of making you look like a character from the *Matrix*, or a friend of Batman who's borrowed his sports cape for a run. It's one of many examples pointing to the future of smart materials in the world of sport and fashion, offering extra utility from your clothes in ways that were previously unimaginable.

Nike Running Division Aerogami
nike.com, from £209.95



...A speaker that truly surrounds

Over the years, Sonos has consolidated its status as a market leader among speaker companies largely thanks to consistency. Rarely taking risks, it focuses simply on great audio and appealing design. In 2023, however, it tried something different. The Era 300 features six optimally positioned drivers on its front, back and sides, creating audio that bounces all around to emulate surround sound, but at a lower price and from a more compact unit. Not only does it sound great, emulating a full array of speakers, but it retains the trademark sleek look. Also in Sonos style, it isn't exactly a budget option, but the Era 100 offers similar, though smaller-scale, results for £200 less.

Sonos Era 300
sonos.com, £449



...A sense of flying like a bird

Sadly, unless you're the kind of daredevil who dons a wingsuit to leap off a high cliff, your chances of actually flying are limited. Now DJI has created an experience that is, at least visually, pretty similar. The DJI Avata is a first-person-view drone, controller and headset combo (including flying tutorial software) that gives the pilot a drone's-eye view as it dives, flies and soars. The drone itself is packed with safety features to reduce the chances of crashing. Paired with incredibly high-quality cameras and other features enabling highly technical video shoots, the launch of the DJI Avata represents a huge leap forward in both drone and video-making technology.

DJI Avata
store.dji.com, from £759



...The future of video calls

With more of us spending more time working from home, there's a need for better video calls (if only to save us from the headaches we get from squinting to read the book titles on our colleagues' shelves). Google's Project Starline aims to not only deliver better video calls, but also inject some personality. Multiple cameras and sensors capture high-resolution images and depth information that, along with machine-learning algorithms, is used to create 3D images of the participants. So even if the person you're chatting to is on the other side of the world, they'll appear to be sitting right across from you. Although Google isn't the only company tapping into the boom in video calls (various competitors are creating their own video call booths), the improved 2023 prototype from the search engine giant has demonstrated it's certainly ahead of the curve.

Google Project Starline
blog.google, £TBC



...The VR headset of the future

Since the invention of virtual reality, there have been plenty of pretty woeful attempts at creating user-friendly VR experiences. Many headsets have been poorly designed, expensive and either very heavy themselves or weighed down by a tangle of cables. But in 2023, VR finally started to look like a viable venture, thanks to the launch of the Meta Quest 3 (from the brand previously known as Facebook) and the announcement of a surprise entry from Apple. The Vision Pro (above), is due for release in 2024 and will be pricey, but looks likely to push VR to new heights by improving visual quality, reducing motion sickness and generally making the experience more tolerable.

Apple Vision Pro
apple.com, \$3,499 (£2,760 approx)



...A light-up smartphone

By and large, smartphones are all much of a muchness. If they're not flipping and folding, they're sitting there looking pretty identical. So how do you get yours to stand out? By adding flashing lights to the back. Now on its second iteration, the Nothing Phone features the Glyph Interface – an array of lights that flash in varying patterns to indicate a text, a call, a Tinder notification or even just when your battery is low. The idea is to limit smartphone use for a less intrusive experience. Winning design awards throughout 2023, it's not just a gimmick – this is actually a good smartphone packing a fast user interface, a powerful processor and a great camera.

Nothing Phone (2)
nothing.tech, from £499





...Water created from air

Extracting water from the atmosphere isn't a new idea (the Inca did it), but it's never come slicker than Spout. Using a six-stage filtration process, it can generate 10 litres (approx 2 gallons) of clean water a day, while removing impurities such as mould spores and allergens. This clever piece of kit is especially useful in places where tap water isn't safe to drink, hugely reducing the cost (after the initial outlay) and environmental impact of buying water bottled in single-use plastic. The machine itself looks great, with a futuristic design that perfectly complements a modern kitchen.

Spout Atmospheric Water Generator
spoutwater.com, \$799 (£630 approx)



...Music for the deaf community

The 'Music: Not Impossible' project has been running since 2018, but 2023 saw it come to fruition, with the unveiling of this haptic device to bring music to deaf gig-goers. Sensors and elements built into a harness, wristbands and ankle bands vibrate to create a 'Surround Body Experience' of complex polyphonic musical expressions across the wearer's skin. In tests at poetry readings, live music performances and club nights, deaf and hearing participants reported an enhanced and intimate experience.

Music: Not Impossible
notimpossible.com, £TBC



....A scooter for all situations

The Gogoro CrossOver looks like a scooter, drives like a scooter and feels like a scooter – yet Gogoro calls it an SUV. However you classify it, though, this is a nifty piece of kit. Essentially a big e-scooter with batteries that can be swapped on the move, the CrossOver is exceptionally customisable. An array of accessories and mounts can be fitted to 26 locking points, while four compartments offer a surprising amount of storage for its size. Designed for both city riding and more rugged rural tracks, the CrossOver has a powerful motor and an all-terrain build ready for any path, beaten or not. Initially launched in Taiwan in 2023, the CrossOver is now being rolled out further afield.

Gogoro CrossOver
gogoro.com, from NT\$82,800 (£2,100 approx)



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HOW TO MASTER YOUR METABOLISM

Ready to welcome a leaner, healthier you? It's time for a metabolic makeover. With a few simple, research-backed changes, you can supercharge your body's calorie-burning

by JAMES WITTS



Metabolism: it isn't what you (probably) think it is. Strictly speaking, your metabolism is the sum of every chemical reaction in every one of your cells – the total energy you burn each day.

Suffice to say, it's quite complex. But, when thinking about weight loss, your metabolism can be broken down into several key components. The most significant of these, which guzzles up around 60 per cent of your daily calories, is basal metabolism.

"Basal metabolic rate is the number of calories your body's using on a minute-by-minute, hour-by-hour basis when at rest, simply to keep going," says Dr Adam Collins, Associate Professor of Nutrition at the University of Surrey. As he explains, basal metabolism is the energy expenditure of basic bodily functions – from pumping materials between cells to maintaining your circulation and vital organs. Your brain and liver alone account for half of your energy costs at rest.

Collins – who's worked with people from all sectors of society, from sedentary types to elite athletes – knows the importance of metabolic health for quality of life, whether that's ascending stairs or racing faster at the business end of a marathon. He also has a revelation for you: any weight-loss programme isn't all about accelerating your essential processes.

"Some people think they're obese because they have a slow metabolism," he says. "But, unless you have an underactive thyroid, generally that's not the case. Actually, the larger you are, the *faster* your resting metabolic rate is compared with that of a leaner individual – your body demands *more* calories just to keep going."

In a clinical setting, it's possible to calculate your exact resting metabolic rate – calorie requirements – using an astronaut-style helmet and analysis machine. When I tried it at Liverpool John Moores University, mine clocked in at around 1,900 calories per day. (I'm 1.89m/6ft 2in tall and 90kg/198lbs). That's at the high end; for most people, it's between 1,000 and 2,200 calories. →

GETTY IMAGES X2

→ “It’s also worth noting that your metabolic rate will probably drop if you diet, exercise and lose weight,” says Collins. This is evident in elite athletes whose metabolism is so dialled in and efficient that their hearts barely beat and their lungs resemble bellows. For them – being capable of, say, cycling over a high Alpine pass – sustaining a sedentary life is child’s play. One famous example from sporting circles is five-time Tour de France winner Miguel Induráin, whose resting heart rate was a mere 28bpm.

Though clearly important, your basal rate isn’t the entire jigsaw, but it is a piece of it. “Arguably more important is that we look at a person’s metabolism as containing three elements,” says Javier Gonzalez, Professor of Nutrition and Metabolism at the University of Bath.

“First, you have your resting [basal] metabolic rate. Then there’s the thermic effect of food – the energy required to digest and metabolise what we eat, typically about 10 per cent of our overall energy expenditure. Finally, you have physical activity. This is the component that we can manipulate significantly, by changing how much we move.”

In other words, improving your metabolic health doesn’t have to be a gruelling war on one front. Instead, there are several simple, science-backed lines of attack to increase your calorie expenditure. Here are the most effective...

UP STRENGTH TRAINING

In general, the more muscular you are, the higher your resting metabolic rate. That’s why hitting the gym may yield greater metabolic dividends than swimming, cycling or running. “To a degree, all types of exercise will build muscle,” says Collins. “But clearly you’ll build greater muscle mass if you strength train.”

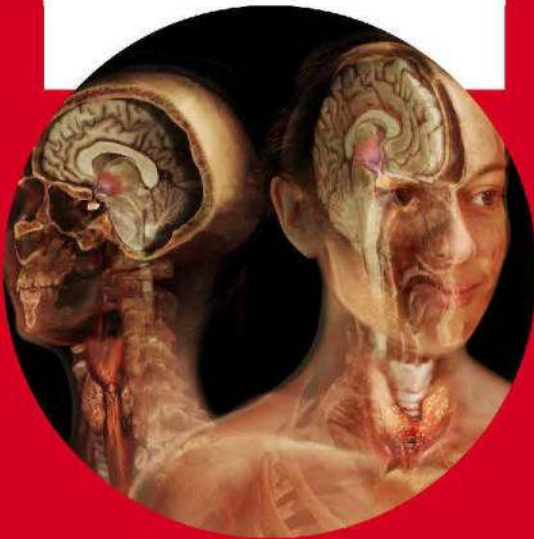
Lifting weights damages muscle, prompting it to repair and rebuild. Do this consistently and you’ll add muscle mass, which burns through calories during the workout and keeps them smouldering afterwards.

“This is known as the ‘afterburn effect’,” says Collins. “The more technical description is excess post-exercise oxygen consumption (EPOC). As you recover from high-intensity exercise, you go from creating energy anaerobically [without oxygen present] to aerobically. This ‘aerobic recovery’ involves tapping into swathes of oxygen to facilitate fat burning. Basically, that energy debt you’ve built up through bench presses needs to be paid back and you do that by metabolising fats.” Essentially, your muscles become a

metabolic sink, so you slice through the fatty stuff rather than storing it.

MAXIMISE MUSCLE

Strength work becomes even more important as you age. A classic 1977 study revealed that resting metabolic rate gradually declines alongside the loss of muscle mass that begins in your 30s. Since then, further research has corroborated those findings. A 2007 study showed for men aged between 50 and 80, the number of fibres in the large thigh muscle, the *vastus lateralis*, decreased by 50 per cent, from 600,000 fibres to 323,000. A key cause is dwindling testosterone levels. Thankfully, pumping iron is an anabolic activity, generating higher levels of testosterone and, thus, muscle. As for what exercises you should focus on, engaging the major muscle groups elicits the greatest testosterone release for a bigger metabolic hit. So you should target the *gluteus maximus* (aka your major buttock muscle) – the largest muscle in your body – which is engaged by exercises such as squats. Remember: it’s always best to start at rock bottom.



ABOVE An underactive thyroid, the gland at the base of your neck, could slow your metabolism

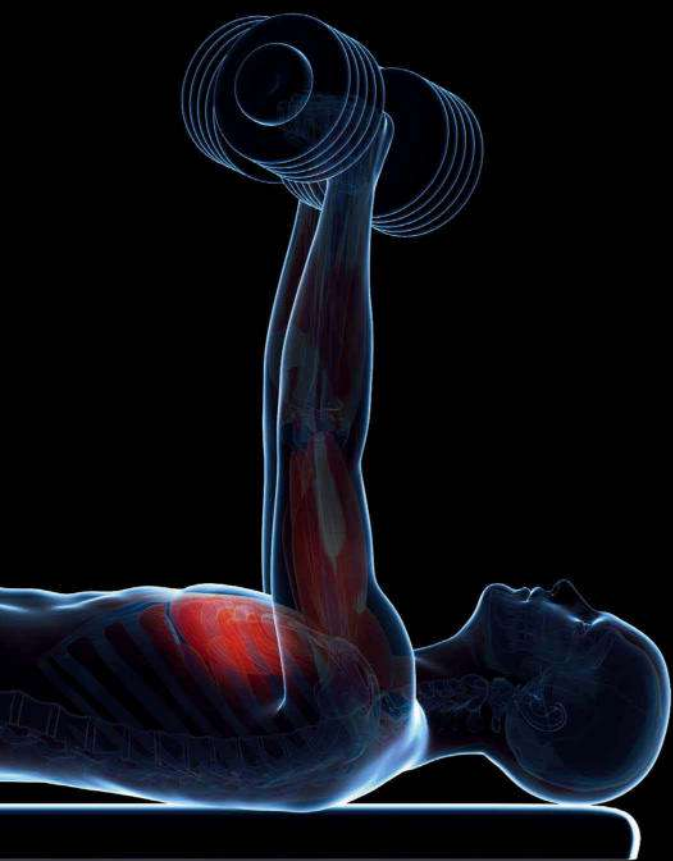




BURN BROWN FAT

ABOVE Cold-water swimming could kick-start your brown fat's metabolism-boosting powers

LEFT Lifting weights builds muscle mass, burning more calories faster



"HITTING THE GYM MAY YIELD GREATER METABOLIC DIVIDENDS THAN CYCLING OR RUNNING"

How did Neanderthals survive cold conditions? It's a poser that troubled the esteemed anthropologist Theodore Steegmann. After all, animal-hide clothing would provide meagre protection against a fierce winter. Eventually, he found the answer: brown adipose tissue.

"This is a type of fat that sits between the muscle and 'traditional' white fat," says Gonzalez. "It's packed with more mitochondria than white fat, which means it's extremely good at burning off excess energy and generating heat."

White fat provides insulation, but brown adipose tissue is the only mammalian cell whose sole purpose is to generate body heat – a process called thermogenesis. Initially, it was thought that the role of brown fat was important only in babies. One of the many challenges facing newborns is the need to maintain a stable temperature. With a relatively high surface-area-to-body-mass ratio, they haemorrhage heat. But when core body temperature drops, brown fat can be activated, sucking up white fat and creating heat energy.

As scanning equipment became more advanced, though, it became clear that brown fat plays a part in the metabolism of people of all ages. So how do you activate your brown fat stores and tap into the thermic metabolic effect? "It's activated in cold conditions," says Gonzalez. "Admittedly how it affects our daily expenditure might not be hugely significant, but it could be one benefit of training in the cold."

You could try cold-water swimming, for example. An analysis of 104 studies concluded this activity could not only significantly increase your insulin sensitivity, but also kick-start your brown fat's metabolism-boosting powers. If you do fancy an icy plunge, though, do so with a friend and have warm clothes to hand.



**“IN RESPONSE TO THIS FUEL CRISIS,
YOUR MUSCLES BECOME BETTER AT
TAKING UP AND USING FUEL”**

INCREASE PROTEIN INTAKE

Protein is key to boosting metabolic health for two reasons: it plays a key role in building muscle and it takes a lot of energy to digest. “The thermic effect of food depends on a few factors, but mainly whether you’re digesting carbohydrates, fat or protein,” says Gonzalez.

“Protein has a much greater thermic effect” – that is, the energy required to digest each macronutrient as a percentage of the energy provided. “The thermic effect of fats is less than 3 per cent, carbohydrates up to 10 per cent, and protein 20 to 30 per cent. So if you consume 1,000 calories of protein, you’ll expend 200 to 300 calories simply digesting it. That’s why protein is so powerful if you’re looking to cut weight, but maintain muscle mass.”

Protein also stimulates muscle protein synthesis and, hence, muscle growth, improving your basal metabolic health.

But it’s not just what you eat that matters. The timing is also important for maximising muscle growth and raising your metabolic

foundations. You should aim to consume protein within an hour of finishing your workout. The optimal intake is around 20g – a pint of milk or four medium eggs, say – though the ideal amount depends on the type, duration and intensity of exercise.

BEDTIME BOOST

Research led by Luc van Loon, Professor of Physiology of Exercise and Nutrition at Maastricht University, suggests that the lack of muscle stimulation overnight curbs muscle growth. It also showed that consuming protein just before sleeping can increase levels of available amino acids in the blood, improving overnight muscle reconditioning. So a glass of milk, possibly with a spoonful of protein powder, should be your go-to nightcap for a metabolic uplift.

BELOW A glass of milk before bed could help improve muscle repair and growth overnight



LEFT A pre-breakfast run could make your body more efficient at burning fat for fuel

EXERCISE FASTED

Strength work is great, certainly, but it's ideally complemented by cardio work. Not only does variety boost motivation, but more steady-state efforts will also yield metabolic benefits, especially if you train hungry and depleted of glycogen (carbohydrate stores in your body) – heading out for a run before breakfast, say.

“The reason your body adapts to long, low-to-moderate intensity exercise is down to the shock,” says Collins. “It’s under metabolic stress, and is running out of fuel. So it starts to adjust by increasing blood supply, the number of mitochondria [cellular powerpacks] within the muscle, and the ability to take up and burn fat. In response to this fuel crisis, your muscles become better at taking up and using fuel. This effect is amplified by glycogen depletion.”

As a result of these changes, your body becomes more efficient at using fat as fuel. All of this contributes to raising your FatMax – the exercise intensity at which you burn the greatest amount of fat for fuel. Research suggests that optimal FatMax is reached at heart rates around 75 per cent of maximum for elite athletes, dropping to around 60 per cent for the rest of us.

Training fasted may be a proven fat burner, but do it judiciously – it can strain your immune system. Best start with a 30-minute fasted jog once a week, then add 10 minutes to that session each week until you push it up to an hour. In not too long, you’ll become a vacuum for fat.

PLAY THE LONG GAME

Your suspicions were right all along: your body *is* trying to sabotage your weight-loss plans. In fact, any time you’re running a calorie deficit, your body will go all out to try and redress the balance. If you take in less energy than you use, levels of the satiety hormone leptin will drop – so you’ll feel less full – while levels of hunger hormone ghrelin will rise, stimulating your appetite. As Collins puts it: “There will be *strong* drivers to down your dieting tools.”

In short, shedding extra pounds through dieting isn’t an easy feat (though the tips in this article will help) – and changes in your metabolism then make *maintaining* your desired weight a challenge.

Why? As we’ve seen, more body mass means more energy required to function – and vice versa. When you drop the pounds, your body needs fewer calories each day – your metabolic rate will be lower. So what was previously a calorie deficit becomes just the right number of calories to maintain your body.

What this means is that, if you resume your old diet upon reaching

your target weight, your waist size will likely sneak back up.

The solution? In theory, it’s simple: stick with your new, low-calorie diet even after you hit your goal weight. Your metabolic rate is lower, so what was once a calorie deficit needs to be your new normal. “It’s all about energy balance – your calories in and calories out,” explains Collins. “It’s about adjusting to a new level and then maintaining it.”

SHIFT PERSPECTIVES AND POUNDS

This metabolic biology might sound miserable – who wants to diet forever? Yet, as Collins argues, a simple perspective shift can be powerful. Instead of seeing your journey as solely going from weight A to weight B, view it as a complete lifestyle change – something that will improve your health for decades.

“Holistically, it’s really worth losing excess weight,” says Collins. “This can, for instance, help clear blood lipids more effectively and aid control of blood glucose levels. Both are key when it comes to improving your overall health,” Collins says.

Adopting these behaviours isn’t just a way to improve your metabolism and shrink your waistline – it’s all a part of becoming a healthier, happier (and, yes, smugger) version of you. **SF**



ABOVE Dieting reduces levels of the satiety hormone leptin, making you feel less full

by JAMES WITTS

James is a science writer specialising in health and fitness. His latest book is *Riding with the Rocketmen* (£14.99, Bloomsbury).



MARS COLONIES
WEIGHT-LOSS PILLS
LAB-GROWN BABIES

CLIMATE FIXES CANCER BREAKTHROUGHS AGELESS BRAINS



Experts reveal what
science will make possible
within our lifetimes

IS LIVING ON MARS A BILLIONAIRE'S FANTASY?

A base on the Red Planet might be filled with some annoying housemates, but that doesn't mean we can't aspire to setting up a permanent settlement there

by DR KELLY
AND ZACH
WEINERSMITH

Husband and wife team Kelly and Zach are the authors of A City on Mars (£25, Penguin).



On 18 November 2023, SpaceX launched one of the largest rockets ever constructed. Starship marks a step change for humanity's relationship with space – a reusable rocket so powerful that it could carry the mass of today's painstakingly built International Space Station in just two to three launches, and likely quite a bit cheaper. Dreams from the days of the Apollo programme, long squashed by the high cost of space access, are returning – and with them, arguments about the value of space to our species.

As with many experimental rockets, Starship failed to achieve all of its goals. Its first rocket stage exploded, and the second needed to self-destruct. Reactions are illustrative of the divide between space analysts and much of the media (and the public). To many, it was proof of failure. Those in the space-geek community generally viewed it as a success. Starship, a rocket the size of a skyscraper, soared 150km (over 90 miles) at high speed, gathering a trove of valuable data before malfunctioning. Not failure – progress with a bang.

THEATRE OF HOPE

Space settlement researchers occasionally find themselves arguing about the value of space. For the most gung-ho space advocates, it's a theatre of all hope. It's a way to get rich from asteroid resources, to save the environment by offloading people and industry from an overburdened Earth, and a chance to create a second home for humanity that could survive the death of our planet. Others question

why we spend so much on space when we have so many problems on Earth. Some wonder darkly if space billionaires are cultivating a Martian redoubt as a kind of off-world bunker, in case our planet is ruined by climate change or war.

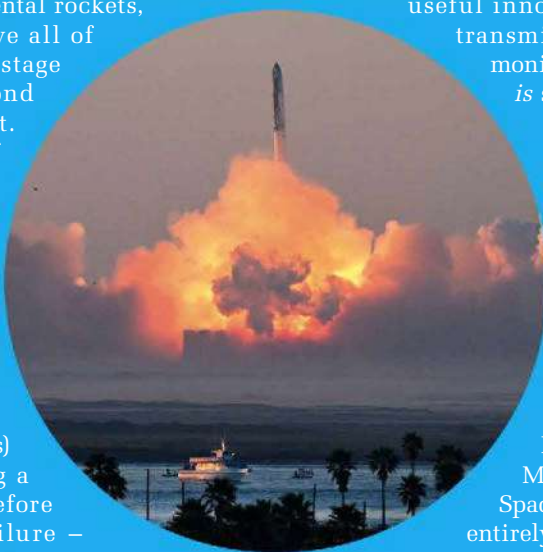
So how well do these arguments hold up?

Should we spend less up there and more down here? True, the space business is booming: estimates suggest it'll be worth over one trillion dollars within the next two decades. But this money isn't being thrown away on space fantasies. Most funds useful innovations: navigation, data transmission and environmental monitoring. So spending up there *is* spending for down here.

Even if every penny spent by governments on space were wasted, that cost would still be dwarfed by spending elsewhere. NASA – the best-funded space agency – receives under half a per cent of the total US budget.

Nor are space billionaires spending huge sums on Martian cities. Though Elon Musk talks of settling Mars, SpaceX's rockets are used almost entirely for satellites local to Earth.

What about space resources? Will mining asteroids lift us all out of poverty, or at least make somebody unfathomably wealthy? We're sceptical. Space resources certainly have value, but accessing a lot of currently valuable stuff is unlikely to eliminate poverty. Consider aluminium: once so precious that it was used to cap the Washington Monument, today we use it to wrap leftover lasagne. Our lives have certainly been enriched by aluminium, but it hasn't made us all richer. As such, we should be wary of any



ABOVE Mars is the most likely planet for human settlement, but we're still a long way from solving the problems that would arise

LEFT SpaceX's Starship blasts off on its test launch on 18 November 2023. The mission ended in explosions, but wasn't necessarily a failure

ALAMY, GETTY IMAGES



narrative that promises a specific dollar return for, say, mining asteroids or the Moon.

In any case, we can't gather these resources yet – nor likely for a long time. Asteroids aren't closely packed lumps of solid platinum. Many are loosely held-together agglomerations of rock and stone, spread thinly across space. Just reaching an asteroid will take months, and extracting valuable material will be incredibly difficult.

WEALTH OF IDEAS

Bear in mind when considering any scheme to gather and exploit extraterrestrial resources that, despite common misconceptions, most wealth doesn't come from stuff. According to the World Bank, non-renewable resources (such as those you would extract from asteroids) make up only about 2.5 per cent of Earth's wealth. The rest comes from ideas and technology – from us.

Many space advocates say that's missing the point: why focus on the value of minerals on Earth? The value proposition is in building infrastructure in space, allowing outbound migrants to enjoy exciting lives while easing the burden on Earth's biosphere.

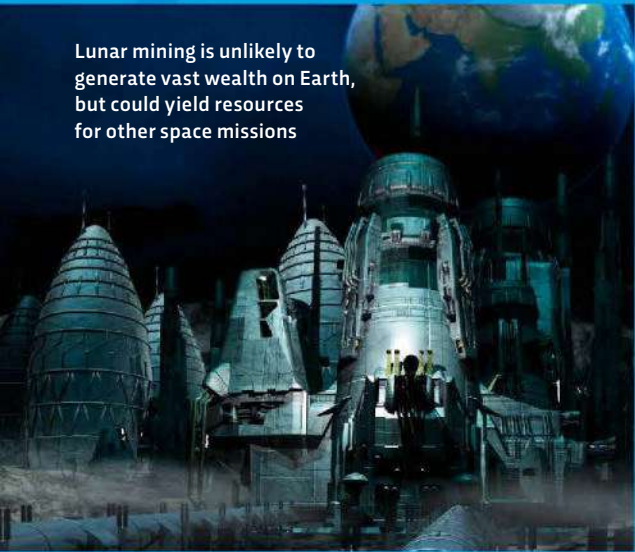
That may become plausible one day, but the numbers are daunting. In 2022, Earth gained 80

"REJECTING UNLIKELY SPACE FANTASIES DOESN'T MEAN WE ALSO HAVE TO REJECT SPACE EXPLORATION OR PROGRESS"

million people. So, just to tread water, we'd need to move 220,000 volunteers per day. For context, today's ISS has a crew of six. Starship, filled to capacity, could take around 100 humans per launch. Perhaps we can scale to these numbers eventually – but not in time to halt climate change.

Consider the most likely destination for those space settlers: Mars. The journey there, which takes about six months, can be launched only every two years. Light takes about three minutes to cover that distance, rendering live chat impossible. The atmosphere on Mars is only about one per cent the thickness of Earth's, and largely carbon dioxide. →

Lunar mining is unlikely to generate vast wealth on Earth, but could yield resources for other space missions



→ With that thin atmosphere, plus the lack of a strong magnetosphere, anyone on the Martian surface will be exposed to high levels of space radiation. Serious plans for habitation involve living beneath Martian dirt, which is nasty stuff: sharp dust and fines that are likely bad for both equipment and lungs, mixed with hormone-disrupting chemicals. And all whipped up by periodic dust storms that can engulf the entire planet.

BIOLOGY LESSONS

Many questions about biology linger, too. Can we have babies on Mars, with these problems and only 40 per cent of Earth's gravity? Can those babies grow up to have their own children? The science of animal reproduction in space is rudimentary, so little can be said for sure. Nor do we know how to construct the enormous sealed ecosystems probably required to create and recycle food, water and air.

Getting these sorts of data would be the work of decades if they were well-funded projects starting immediately – and neither governments nor space billionaires appear to be shelling out such funds.

This returns us to our earlier question: are billionaires planning to use Mars as a distant sanctuary? We suspect not. Almost nothing you could do to Earth would make it as inhospitable as Mars. Nuclear war would still leave a functioning biosphere, as would runaway climate change. Even the asteroid that wiped out the dinosaurs spared humankind's ancestors. If billionaires believe this is a good escape plan, they're even more foolish than they sound on social media.

But rejecting unlikely space fantasies doesn't mean we also have to reject space exploration or progress. Whether an en-masse space migration is possible or even desirable, space exploration will remain a source of economic growth, useful information and beautiful truths. There may not be a space economy beyond providing data about Earth, but those benefits are real and growing.

ALAMY, GETTY IMAGES



COULD A PILL REALLY HELP US LOSE WEIGHT?

Cutting-edge weight-loss treatments might be around the corner. But can they end obesity?



PROF BARBARA
MCGOWAN

Barbara chairs the UK Obesity Management Collaborative, and is Chief Medical Officer at digital weight management company Roczen.

The way we think about obesity has undergone a profound shift in recent years. Previously viewed as an individual lifestyle choice, it is now recognised as a complex disease influenced by genetics, biology, psychosocial factors and the environment. We also know that it affects a huge proportion of people. The World Health Organization estimates that nearly two billion adults are overweight or obese, with numbers now soaring dramatically in low-, middle- and high-income countries alike.

This is a major problem: excess body fat (adipose tissue) increases the risk of diseases such as diabetes, heart disease, dementia, cancer, non-alcoholic fatty liver disease and kidney failure.

Fortunately, recent discoveries are helping us understand more about obesity. For instance, over

the past 30 years, we have learned that energy balance and eating behaviour are regulated not in the stomach, but in the brain. Scientists have discovered hundreds of genes that affect our bodies' weight regulation, some of which predispose us to obesity. We also know that maintaining weight loss is difficult for a lot of people because of the body's natural responses: weight loss causes our metabolisms to slow down and hunger hormones to increase. This evolving understanding has driven significant efforts to find effective treatments for people living with obesity, who are often stigmatised and discriminated against.

Traditionally, weight-loss strategies have been based on either surgery or lifestyle changes such as diet and exercise. Surgery can be an effective option, but it's not without risks, and can →



DR LAURA
FALVEY

Laura is a medical doctor trained at King's College London, and is certified with the World Obesity Federation. She is the clinical director at Roczen.

→ potentially have long-term or irreversible effects. It's also expensive, and availability is limited.

Could weight-loss drugs soon offer a silver bullet? So far, they haven't proved to be very effective. Take orlistat, for instance, which functions by inhibiting the absorption of fat in the intestines. Though not unsafe, it produces a mere 3 per cent body weight loss, and necessitates dietary restrictions. Others, such as combined phentermine-topiramate (not licensed in the UK), act on the central nervous system to activate 'fight or flight' responses and increase energy expenditure. This, as you might guess, may pose risks to the cardiovascular system.

IMPEDING APPETITE

The future of weight-loss medicine may lie in new gut-hormone therapies called incretins. These peptides – chains of amino acids – are naturally produced in the body in response to food intake, and can help regulate appetite via the gut-brain axis. Examples include glucagon, gastric inhibitory peptide, and glucagon-like peptide 1 (GLP-1).

Current medicines licensed for obesity, such as semaglutide (sold under the brand names Wegovy in the UK and Ozempic in the US), activate the GLP-1 hormone pathway. Upcoming 'twincretin' medicines, such as Tirzepatide, go further by combining two hormones delivered by one pen injector. These therapies produce significant body weight loss, improve conditions such as high blood sugar, and have been shown in large clinical trials to produce largely manageable side effects. Importantly, Wegovy has been shown to reduce the risk of cardiovascular events in a promising preview of what we hope is to come – effective obesity management and timely disease prevention.

However, these new medications are not without challenges. First, most must be injected by patients, many of whom are averse to doing so. Second, clinical trials have so far shown that weight gain restarts when medication is stopped. And that's before we look at the high costs of manufacture and distribution for drugs that need to be stored in cool conditions, and the fact that demand heavily outweighs supply. This is a big problem: we know that people who live with obesity are more likely to be in lower socioeconomic groups, so expensive solutions will likely widen health inequalities.

"A PILL COULD BE ONE EFFECTIVE TOOL, BUT IT CAN'T TOTALLY REPLACE HEALTHY HABITS AND PSYCHOLOGICAL WELLBEING"

ABOVE Some weight-loss medicines such as orlistat aren't very effective

RIGHT Excess body fat increases risk of diseases



Ultimately, any 'magic pill' for weight loss must be both safe and effective, with manageable side effects and great outcomes for patients in terms of overall physical and mental health. It also needs to be cheap to produce, so that all patients who need it can access it. It wouldn't just affect numbers on weighing scales but would improve patients' quality of life, too.

More innovative weight-loss pills may just be around the corner. With industry giants such as Novo Nordisk, Eli Lilly, Pfizer, Boehringer Ingelheim and AstraZeneca leading the charge, numerous new medications are anticipated in the next 30 years.

Eli Lilly appears to have in its pipeline the most promising oral medication: a small-molecule non-peptide named orforglipron. Currently undergoing phase 3 clinical trials, the medication signals fullness to the brain, stimulating insulin release



and slowing the speed at **which** food travels through the digestive tract, making recipients feel fuller for longer. Phase 2 clinical trials showed nearly 15 per cent body weight loss at 36 weeks.

However, it's hard to say exactly when these drugs will be released. Predicting the timeline for such breakthroughs is challenging, not least because of the difficulties in bringing new medications to market – it's a time-consuming and expensive process with few successes. In addition, weight-loss medication has historically produced severe side effects, so there is an emphasis on ensuring safety over longer-term use.

INTRIGUING FUTURE

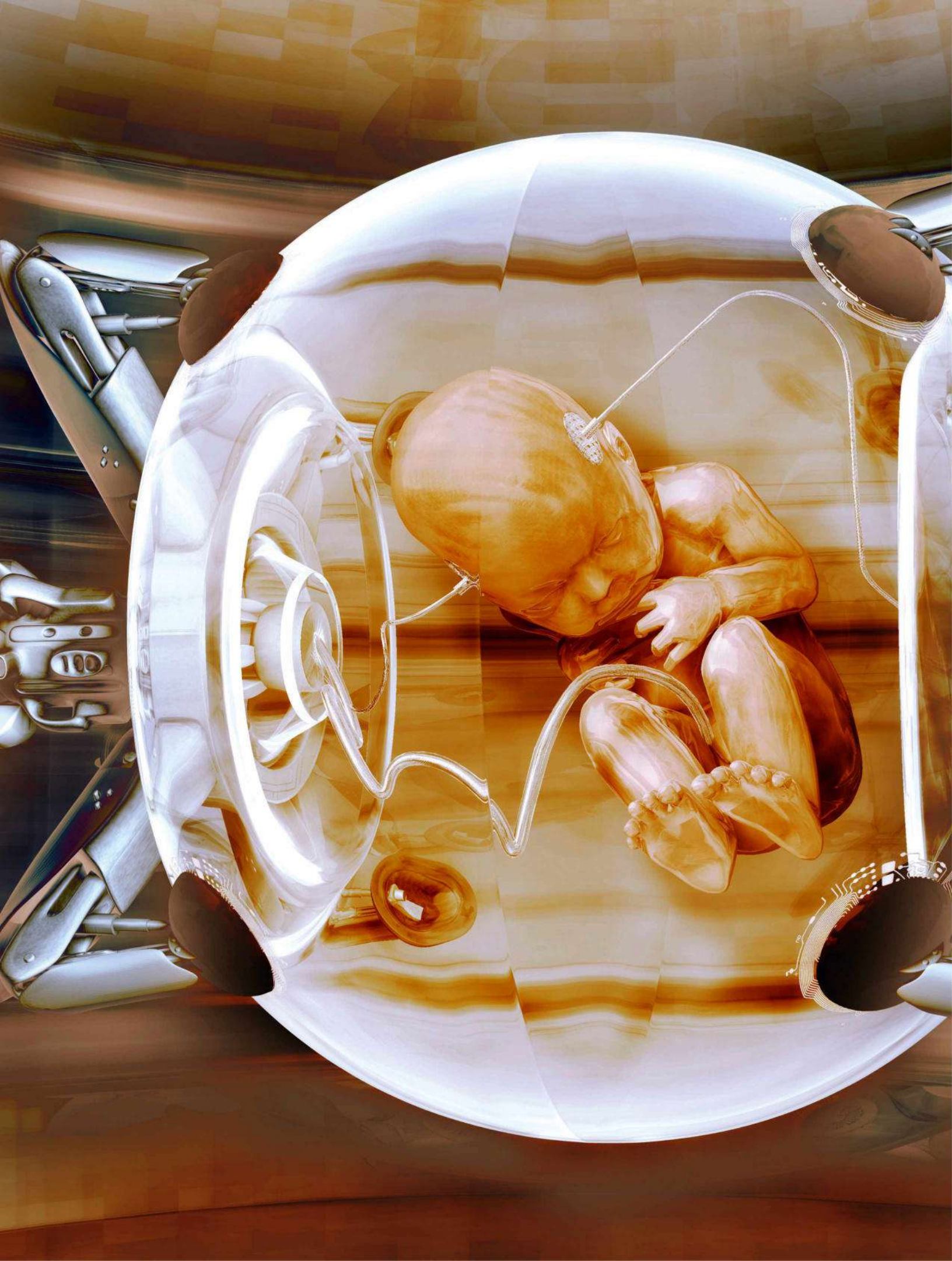
Despite these challenges, the future of obesity treatment is exciting and intriguing because developing weight-loss medication involves navigating the complexities of human biology.

One promising avenue might be developing medication that stimulates natural fat-burning pathways, perhaps manipulating certain types of fat. For instance, brown adipose tissue can break down glucose and fat molecules to create heat and maintain body temperature. Could a drug be made to harness this effect? Other hormones under investigation include amylin, secreted at the same time as insulin. Finally, advancing technologies such as gene therapy, nanotechnology and CRISPR gene-editing offer potential pathways for developing effective treatments.

Whatever advances are made, though, a 'magic' weight-loss pill won't provide a single effective way to combat obesity within the next few decades. It's important to note that appropriately supported, clinically led lifestyle changes can be very effective for some patients, as can surgery. Patients living with obesity have the right to access the right treatment pathway for them, and we must work to remove the stigma attached to obesity.

A pill could be an effective tool, but just one of many. It can't totally replace healthy habits and psychological wellbeing, nor address the socioeconomic factors that drive health inequalities. Psychological factors, such as disordered eating and trauma, are other crucial targets in the treatment of obesity – yet they're currently overlooked in favour of pharmacological solutions. So, though the promise of a weight-loss pill is certainly exciting, it should be viewed as one potential option in a larger toolbox rather than a standalone solution.

Ultimately, the development of a safe and effective weight-loss pill still faces multiple challenges, from biological and psychological complexities to practical considerations including cost. Previous failures to recognise obesity as a chronic disease, plus widespread prejudice against those living with obesity, have hindered progress. With the advent of new medications and a focus on the gut-brain axis, however, there's cause for real hope.



WILL SEX BECOME OBSOLETE?

New technologies could reimagine baby-making as we know it. But will they actually replace tried-and-tested (and enjoyable) methods?



PROF HENRY
T. GREELY

Henry is the author of The End of Sex and the Future of Human Reproduction (£26.95, Harvard University Press).

Over the past decade, I have made some bold predictions about the future of sex. One that's been easy is that people will still be having sex for years to come, but for different reasons: they simply won't do it so much to make babies. That's not to say that making babies will become obsolete, but, rather, that technology will change the ways we do it. There could be a much safer and easier way to reproduce – and sex as we know it could end.

Until about a century ago, humans always created embryos and babies in the same old, largely random way – through sex. Then some started using artificial insemination and, 45 years ago, in vitro fertilisation. Important as these technologies have been, they still involve human eggs and sperm. Thanks to stem cell technologies, though, that will shift.

The step change will be in vitro gametogenesis (IVG) – turning skin cells into induced pluripotent stem cells, then turning those into eggs and sperm. IVG is tremendously exciting to millions of couples, but it does raise some tricky questions. For example, if we could make eggs from skin cells, 90-year-olds could become genetic parents. So could nine-year-olds, miscarried fetuses or people who have been dead for years, but whose cells were frozen.

Also consider this: what if we could make sperm from women's skin cells, or eggs from men's? It could soon be a reality. In 2023, Japanese scientists announced that they had made eggs from a male mouse's skin cells and, using 'normal' mouse sperm, had produced mouse pups.

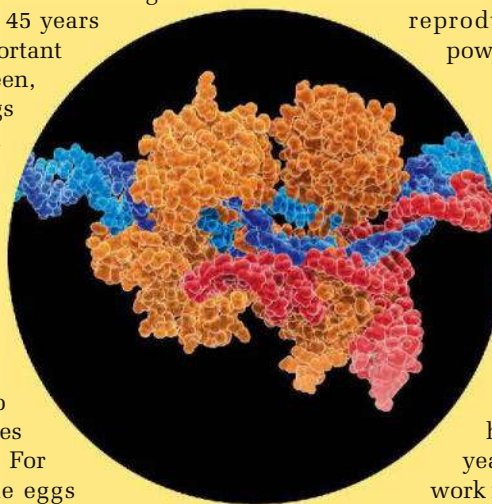
To take this idea further, what if we made both eggs and sperm from the same person and used them to make embryos? Your 'unibaby' wouldn't be a clone, but closer to you than your siblings. An even more radical idea called 'multiplex parenting' could involve making embryos from four people that would then be used to make eggs and sperm. Turn that fertilised egg into a baby and you've got a child with roughly equal genetic contributions from four parents – or eight, or sixteen, or more.

GENE GENIES

Another technology that could end reproduction as we know it is the power to modify an embryo's DNA.

Targeted editing of particular sequences in a cell's DNA has become possible thanks to a revolutionary tool, invented in 2012, targeting CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) DNA sequences (left). In November 2018, Chinese scientist He Jiankui announced the birth of two girls whose embryos he had 'CRISPRed' earlier that year. Unfortunately, he did this work in secret, in ways that violated both human research ethics and Chinese law. A Chinese court sentenced him to three years in prison, and the court of international opinion condemned him as a renegade. (Those first two babies are now over five years old, but China has released no information about their health or genetic makeup.)

When you edit DNA in an early embryo, you edit the DNA in what will become all of its cells – including its eggs and sperm. →



**"IF WE COULD
MAKE EGGS FROM
HUMAN SKIN CELLS,
90-YEAR-OLDS
COULD BECOME
GENETIC PARENTS"**

→ You therefore make a change that can be passed on to that embryo's descendants indefinitely.

The most plausible use of this DNA-editing technology is to prevent diseases or disabling conditions in children. The most frightening, though implausible, use is to use it to create 'super babies' who would not only have greater abilities, but would also pass them on to *their* offspring. Some think that we should never be allowed to change the DNA of our descendants, potentially forever; others think that we shouldn't use it now, because it's not proven safe or effective.

WOMB 101

Another technology that could make sex for reproduction further redundant is the development of artificial wombs. Over 90 years ago, in *Brave New World*, Aldous Huxley predicted 'hatcheries' in which human foetuses would develop in bottles.

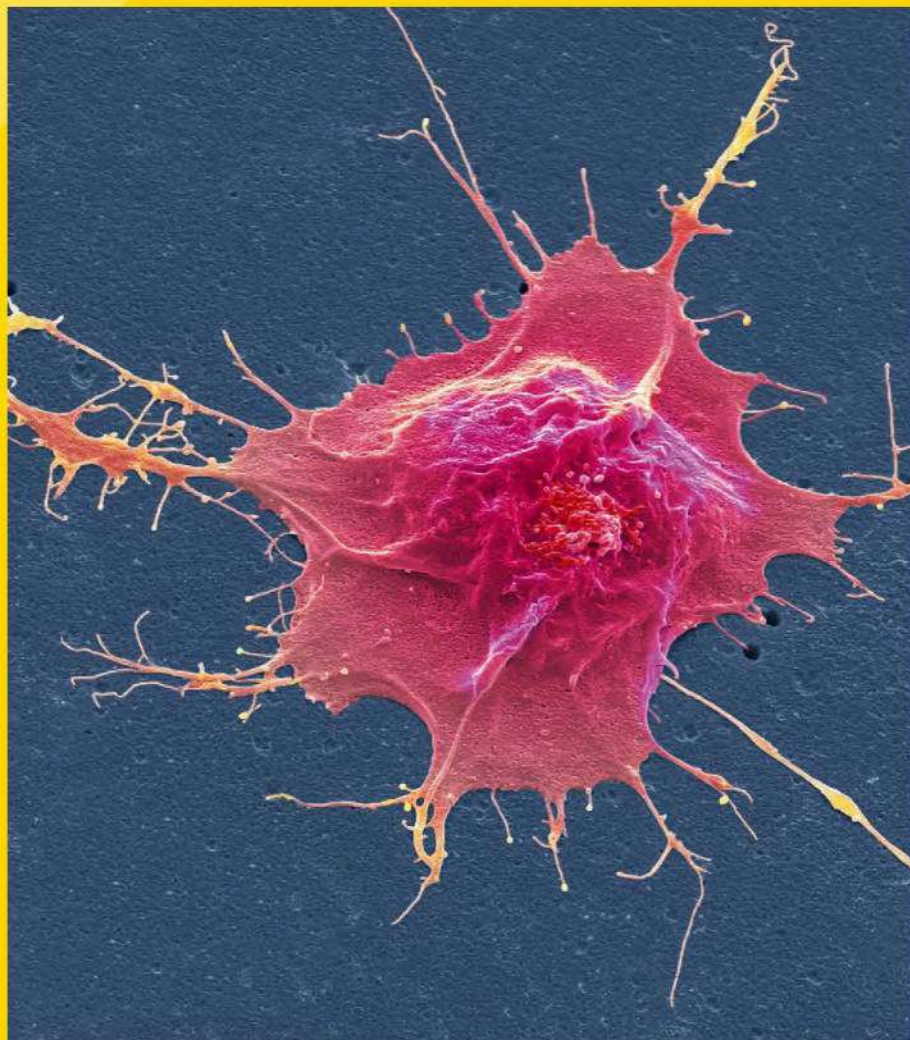
In 2017, researchers reported keeping neonatal lambs born a week or two early alive in fluid-filled plastic bags. More recently, the US Food and Drug Administration held a public meeting to consider whether, when and how to run trials with such artificial wombs on babies.

These devices are, in effect, early incubators. They might push back viability for premature infants a week or two, from (at best) about 22 weeks of pregnancy to nearer 20, but that baby would still need to have spent four and a half months developing inside a woman. This advance could be wonderful for premature infants and their parents, but would not make much difference for most of us.

What about a 'true' artificial uterus – one that could take a six- or seven-day embryo and help it develop over nine months into a healthy newborn? That would remove not only the sex from making babies, but pregnancy as well. Some might welcome it. Others would, no doubt, be concerned.

All this might not be implausible in the far future. A major area of long-term research today is using stem cells to grow human organs. The focus is on vital organs for transplants – kidneys, livers, hearts – but if they can be grown, why not a uterus?

Imagine that organ, grown from a woman's stem cells, hooked up to a machine that would provide blood, sugar, oxygen and all the necessary hormones, as well as waste treatment – then add in an embryo. Such a 'womb in a box' could, in theory at least,



ABOVE Human induced pluripotent cells like this one, created from a skin cell, can be turned into eggs and sperm

take the place of a womb in a woman. But should it? Our children and grandchildren will likely need to make that decision.

This is an amazing time to be involved in medicine and biology. Our knowledge is expanding astonishingly. Our ability to make good use of that knowledge is growing more slowly, but steadily. Our understanding of the consequences of using new technologies – and our agreement on what limits, if any, should be placed on it – are growing more slowly still.

Making babies artificially is not an exception, though it is special in one important way. I am able to consent to an experimental procedure, agreeing to the risks in return for potential benefits to myself or to science. Babies can't consent; nor can embryos. That doesn't mean that we shouldn't ever use new technologies in reproduction, but it does mean that we should be especially careful to test the technologies to make sure that they are safe and effective – for the babies. We need to emphasise their welfare first, then the broader effects on our societies.

"A 'TRUE' ARTIFICIAL UTERUS COULD TAKE A SIX- OR SEVEN-DAY EMBRYO AND HELP IT DEVELOP OVER NINE MONTHS INTO A HEALTHY NEWBORN"

If we're to mitigate the effects of climate change, we need to curb carbon emissions now using existing technology



CAN TECH SAVE US FROM CLIMATE CHANGE?

The one thing we need to save us from climate catastrophe is the one thing technology can't provide — time



DR JONATHAN FOLEY

Jonathan is a renowned environmental scientist, sustainability expert and the director of Project Drawdown, the world's leading resource for climate solutions. [Drawdown.org](https://drawdown.org)

As a kid, I was hooked on science fiction TV shows: *Star Trek*, *Doctor Who* and more. My inner nerd loved these incredible stories.

They usually followed a standard plot. A terrible crisis would unfold, threatening almost certain doom, until – in the last few minutes – a hero unveiled a technological wonder that instantly solved the problem. Whether it was Scotty working his miracles on the USS *Enterprise* or the Doctor using his sonic screwdriver, we were sure of one thing: technology would save the day.

I loved those stories when I was a kid. Part of me still does. And I honestly wish that some new technological marvel could save us now by averting the planetary crisis of climate change. I'd love to see a hero swoop in, set their phasers to decarbonise and zap away our greenhouse gases.

Sadly, that's not going to happen. Today, as a scientist, I know why.

The fundamental reason high-tech solutions won't save us from climate change is simple: time. Time is by far the most important variable – and the one thing technology can't give us more of.

Climate change is a cumulative problem. The warming we see now is caused by the year-by-year, decade-by-decade build-up of greenhouse gas pollution in Earth's atmosphere. The severe climate disruptions of 2023 – the record temperatures, storms, fires and other disasters – weren't caused by 2023's emissions alone. Nor were they caused by those of 2022. They were caused by our long-term, cumulative emissions, building up over many, many years.

Over the past several decades we've been emitting a lot of greenhouse gases – tens of billions of tonnes →

"WE SHOULDN'T WAIT FOR FUSION. AS THE WRY SAYING GOES: FUSION ENERGY IS 20 YEARS AWAY... AND IT ALWAYS WILL BE"

→ each year, adding up to a staggering amount of pollution dumped into the atmosphere. The cumulative impact of that pollution has fundamentally changed our atmosphere and climate system.

The longer we keep emitting greenhouse gases, the more this pollution builds up in the atmosphere, and the more climate heating it causes. It's a process that effectively locks in warmer temperatures on our planet for thousands of years to come. The only solution is to stop polluting as quickly (and as safely and equitably) as possible.

To avoid the worst outcomes of climate change, we need to start lowering our emissions immediately. By cutting emissions now, and continuing to cut them in each consecutive year, we can reduce the future impacts of climate change. Every tonne of greenhouse gases we don't emit, starting today, will help reduce the amount of warming we'll see.

Every tonne matters. Every year matters.

SOLUTIONS TODAY FOR SAVING TOMORROW

That's why we need to focus on the solutions we already have. Despite what some think, climate solutions are already here. In fact, today's climate solutions are abundant, whether they're achieving huge gains in efficiency, reducing food waste, deforestation, and other destructive processes, electrifying our homes and vehicles, plugging methane leaks in oil and gas, or switching to zero-carbon energy sources. My organisation, Drawdown.org, is the world's leading resource for learning more.

Better yet, we should focus more attention on the fastest 'emergency break' climate solutions that have an immediate impact on the atmosphere, quickly helping drive down emissions. The top such measures include stopping deforestation (which accounts for about 11 per cent of global emissions – more than the entire US economy), curbing methane emissions (which have a disproportionately fast impact on climate), and cutting energy, food and industrial waste as rapidly as possible. These fast-acting climate solutions can buy us time for other tactics – building new power-generation systems, transmission lines, energy-efficient buildings and transportation infrastructure – to kick in.





The worst possible thing we can do is wait, hoping that a new, 'better' solution will arrive to solve the problem. Waiting means we continue to spew pollution into the atmosphere, locking in more warming. Waiting is the enemy of climate action.

At the COP28 conference in November, Bill Gates once again told the world that we can't solve the worst of the climate crisis with the technologies we have now. But that's not really true. We can – it's just that some of these solutions are inconvenient or expensive. For the most part, we have the tools we need. What we don't have, is time. That's why we shouldn't wait for new technologies.

FUSION'S FOR THE FUTURE

We shouldn't wait for fusion. Government research into fusion energy has been going on since the 1950s, with little of substance to show for it. Despite rosy hype, decades of effort and billions spent, we're still many years away from a commercial energy source. As the wry saying goes: fusion energy is 20 years away... and it always will be.

We shouldn't wait for advanced nuclear power, either. Nuclear energy generation is stagnating across much of the world, hit by lengthy delays and cost overruns. Promises of better, cheaper,

faster, safer nuclear power plants, repeated over decades, have never been met. The last hyped-up technology, the Small Modular Reactor, has recently faced embarrassing delays and failures, casting doubt on the commercial rollout of this technology.

And we shouldn't wait for industrial carbon-capture techniques. After decades of work and tens of billions of dollars spent, such technology is still incredibly ineffective at removing carbon dioxide from the atmosphere. Projects are still laughably small, wildly expensive and consume massive amounts of energy that would be better used elsewhere. It's unlikely that these technologies will make any real dent in the atmosphere for decades to come, if ever. Their only use, so far, is as a PR fig leaf for fossil fuel companies.

In the race against climate change, it's quite simple: time is more important than tech. Wishing and waiting for solutions that may never come is exactly the wrong thing to do.

So, for now, we must stop dreaming about being Captain Kirk or Doctor Who, and start deploying the tools that are available now. There are science-backed solutions we can use today – and there's no time to wait to see what else science fiction can conjure up at the last minute.

ABOVE Halting deforestation in Brazil and elsewhere *now* is essential, rather than waiting for new tech to address climate change

LEFT Scaling up sustainable transport and other fast-acting climate solutions could buy us time to develop other effective tactics

WILL WE EVER CURE CANCER?

One of the most pressing medical challenges facing the world's ageing population is the fight against cancer. But is this a battle that's winnable – and what technologies are being developed to wage the war?



PROF SARAH ALLINSON

Sarah, based at Lancaster University, works to improve understanding of how cells respond to DNA damage.

One in two of us will develop cancer in our lifetime. Thanks to advances in diagnosis and treatment, though, more people are surviving cancer than ever. Will this trend continue – and how close are we to finding a cure?

That upward survival trend is likely to continue. But finding a cure? That's not so easy to answer, for a simple reason: cancer isn't one single disease but a collection of more than 200, each with unique features. Yet every cancer consists of a mass of abnormal cells, all originating from a single mutated cell that began to divide uncontrollably.

Cell division – one cell dividing to produce two new ones – is essential for growing and maintaining our bodies. Cells that have become worn out or damaged must be replaced. This process is tightly controlled, so that cells are produced only when needed, and in the exact numbers and locations required. Cancer cells evade those controls and divide chaotically, while also eluding the back-up systems that suppress growth and weed out abnormally behaving cells. The result is a tumour.

Cancer cells acquire these characteristics through gene mutations. One important group of genes comprises the proto-oncogenes, which mutate to continuously produce a signal telling cancer cells to divide, becoming oncogenes. Turning off that oncogenic signal stops cancer cells dividing and can even kill them. That's the principle underpinning the concept of targeted cancer therapies, a treatment approach in which much progress has been made.

Targeted cancer therapies are more effective and have fewer side effects than traditional treatments such as chemotherapy and radiotherapy, and have now been in use for almost 50 years. The first were hormone therapies used for diseases such as breast and prostate cancer, whose growth depends on the hormones oestrogen and testosterone, respectively.

A further step forward came in the 1990s with the development of imatinib (marketed as Glivec). Developed to inhibit the product of an oncogene present in 99 per cent of chronic myeloid leukaemia



ABOVE Scientists at Stanford University broke records by sequencing a human genome in five hours

ABOVE RIGHT The targeted therapy imatinib has revolutionised treatment of chronic myeloid leukaemia, which affects white blood cells

(CML) cases, it revolutionised CML treatment. Before imatinib, fewer than three in ten CML patients could expect to survive five years beyond diagnosis. Today, nine in ten do.

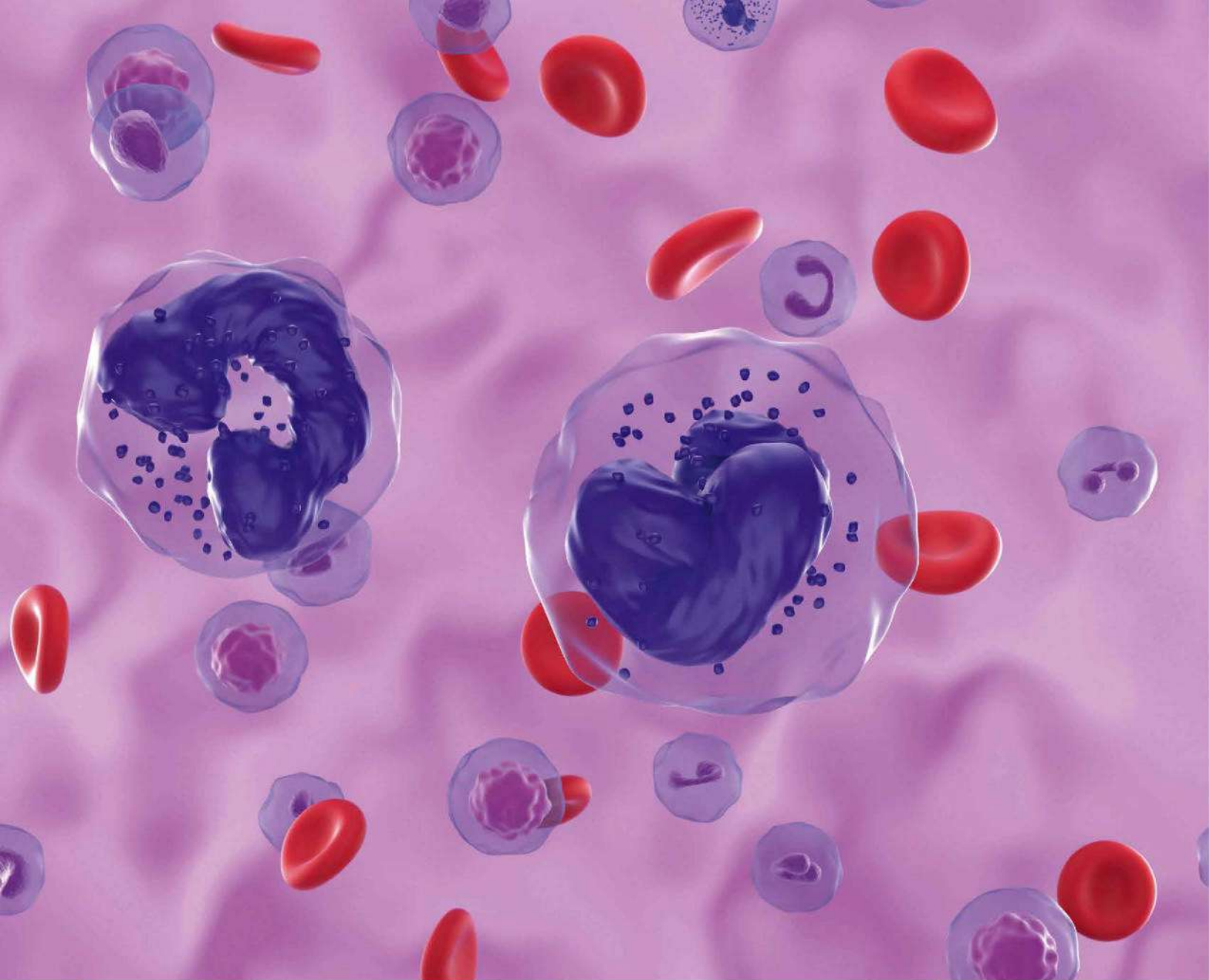
POWER OF BIG DATA

Since imatinib, many more targeted therapies have been developed to tackle a diverse range of cancers, with even more undergoing trials. The process of drug discovery has been greatly accelerated by modern genetic techniques that bring the power of big data to cancer research.

For example, the Cancer Genome Atlas project contains genetic information on tumours from 11,000 people and 33 types of cancer. This can be cross-referenced with patient data, enabling deeper insights into how genetic changes drive cancer and its progression, and points towards new treatments by developing new drugs or repurposing old ones.

One recent success story is the approval of drugs originally developed for treating malignant melanoma for the treatment of some cases of a type





of brain cancer called glioma, after the discovery that their growth was dependent on the same oncogene, BRAF. This approach offers hope to people diagnosed with rare types of cancers for which no drugs are currently available.

Technological advances are also making genome sequencing cheaper and faster, ushering in an era of truly personalised medicine. In 2022, a team at Stanford University announced that they'd sequenced a full human genome in a record-breaking five hours, and aim to translate that into cancer treatment.

In the future, it may become routine to sequence the genome of a patient's tumour before treatment begins. Armed with this information, an oncologist will be able to select from an array of targeted drugs to tailor each patient's treatment exactly, increasing the chance of success.

Drug treatments aren't the only area in which significant progress has been made, though. The past decade has seen rapid progress in the use of immunotherapies for cancer. The various types of cancer immunotherapy aim to boost a patient's

"THE CANCER GENOME ATLAS PROJECT CONTAINS GENETIC INFORMATION ON TUMOURS FROM 11,000 PEOPLE"

immune system so that it's better able to detect and destroy cancerous cells. This field is still in its infancy, and we can expect sustained improvements in these treatments over the next decade.

Immune checkpoint inhibitors comprise a type of drug that prevents cancers from avoiding detection by the immune system. They can be incredibly successful as a treatment, but currently work in only some patients. Adoptive cell therapies harvest T cells from patients to make them more effective in fighting cancer. One very successful example of this is the chimeric antigen receptor T cell (CAR T) →

→ therapy. This involves genetically engineering harvested T cells to bind to a specific antigen on the surface of tumour cells. The modified T cells are then grown in the laboratory before being infused back into the patient's body to fight the cancer.

CAR T cells are very effective against blood cancers, but have been less successful in solid tumours. This might change with new technological advances that include the ability to switch CAR T cells on and off, timing their activity, and the development of longer-lasting CAR T cells.

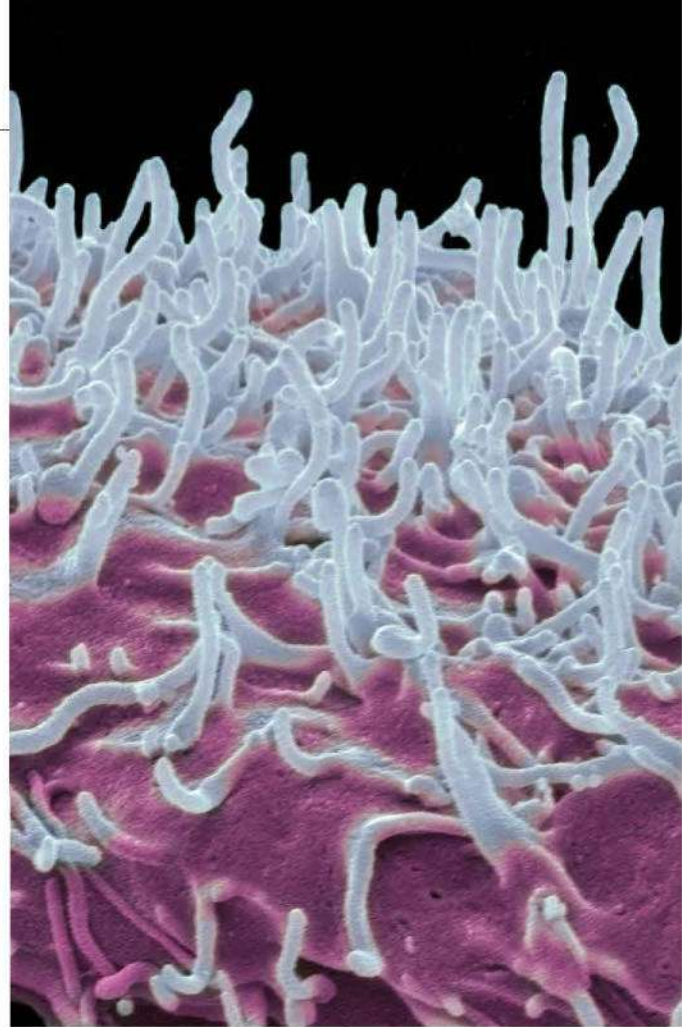
VAX ON TRACK

Progress has also been made in developing immunisation – vaccinating a patient with cancer antigens to help their immune system detect that cancer. Though the concept has been well established in model systems, translating this into the clinical setting has proved tricky. Every tumour has a unique molecular signature, and a vaccine that works in one patient may not work in another.

mRNA-based vaccines are likely to dramatically change the cancer vaccine landscape. Instead of using a cancer antigen to trigger an immune response, the body is instead provided with instructions (in the form of mRNA) to produce the antigen itself. This offers several advantages. First, if the molecular signature of a patient's tumour

RIGHT Drugs first approved for treating melanoma are now being used to tackle some cases of a type of brain cancer called glioma, shown here

SCIENCEPHOTO LIBRARY, GETTY IMAGES



CAN WE STOP COGNITIVE DECLINE?



DR HAYLEY
WRIGHT

Hayley is an Assistant Professor at Coventry University. Research areas include cognitive ageing and neuropsychology.

More of us are living longer, but although our bodies are enduring better, our brains don't always show the same resilience. Could science extend our neurological health to keep pace with physical longevity?

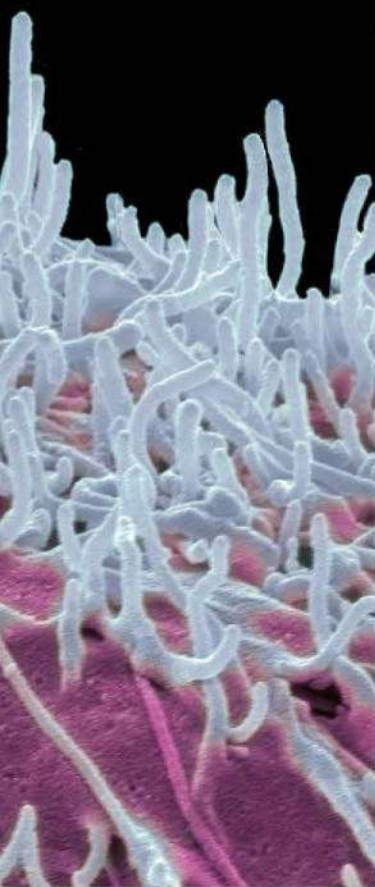
Cognitive decline refers to the slowing or dulling of our memory, concentration and ability to think. It's quite common to become more forgetful as we age – failing to remember someone's name, say, or what we set out to buy at the shops.

Increasingly frequent episodes might, though, indicate cognitive impairment – when the rate of decline is faster than we would expect as part of the normal ageing process. This can be scary for the person experiencing symptoms, as well as for family and friends. Some of the most common signs of cognitive impairment include: forgetting important dates or events; losing your train of thought; becoming increasingly overwhelmed by making decisions or planning tasks; having trouble finding your way around familiar places; and becoming more impulsive.

We all experience cognitive decline as we get older, but the degree and rate of decline is different for everyone, largely determined by genes and family history. So two people with the same level of age-related changes to their brains might perform very differently on cognitive tasks. And two people with Alzheimer's disease can have a similar cognitive ability, but vastly different changes in the brain.

RESILIENCE AND RESERVE

Some people seem to be more resilient to the effects of ageing, possibly because they've developed a larger capacity – or 'cognitive reserve' – to cope with changes. Research shows that cognitive reserve is built up through experiences during our lifetimes, including educational attainments, having an engaging occupation or taking part in stimulating activities. Education and occupation



has been mapped through genome sequencing, the vaccine can be tailored to match. Second, vaccines can be designed to hit multiple targets at once.

Further optimisation, including identifying the best route of delivery, is needed before mRNA cancer vaccines can reach routine clinical use. However, several clinical trials are in progress and showing promising results.

Early diagnosis is as important as treatment, if not more so. The more time a tumour has to grow and evolve, the more difficult treatment becomes.

For some cancers, well-established techniques for early diagnosis already exist: national screening programmes for cervical, breast and colorectal cancers, for example. These have led to better outcomes, with more patients surviving. However, screening tests aren't available for many cancers. Some, such as pancreatic and lung cancers, are often diagnosed quite late.

Artificial intelligence is likely to hold the key to improving cancer diagnosis in the future. It's being applied to a wide range of approaches, including tumour image analysis and the development of smart tests to detect the molecular signatures of tumours from traces in the blood.

Of course, it would be better if cancer could be prevented altogether. Worldwide, up to 20 per cent of all cancers are caused by chronic infection. For

example, infection with high-risk variants of the human papillomavirus (HPV) can cause a range of cancers including cervical, penile, and head and neck cancers. Similarly, chronic infection with Hepatitis B (HBV) is the main cause of liver cancer.

Vaccines against HPV and HBV are already reducing the incidence of their respective cancers. Through a combination of HPV vaccination and cervical screening, NHS England aims to completely eradicate cervical cancer by 2040.

What about cancers that aren't caused by infections? Here the concept of cancer interception offers real promise. This involves using a drug or a vaccine to kill cancer cells as they arise, long before they can form a detectable tumour. It can also be used to prevent cancer from recurring in patients who've been successfully treated for the disease.

Aromatase inhibitors, a type of hormone therapy used for breast cancer, have been used to prevent disease recurrence for years. More recently they have been licensed by the NHS to prevent breast cancer in women who have a high risk of developing it.

The next decade is likely to see further evolution in cancer diagnosis, treatment and prevention. And although we're unlikely to ever see a single 'cure', the ever-growing arsenal we can access to fight the disease offers new hope to cancer patients everywhere.



may be determined in part by socioeconomic status. But participation in activities – leisure pursuits, learning, social interactions – is within our control.

Other health conditions – such as high blood pressure, diabetes, depression and vascular disease – can exacerbate cognitive decline. Some are avoidable or manageable through lifestyle changes. For example, eating a nutritious, balanced diet with lots of leafy and green vegetables; staying physically active; limiting alcohol intake and avoiding tobacco products.

Making positive changes in one area of life can produce benefits in another. Conversely, adopting unhealthy habits can cause a chain reaction or negative spiral of health outcomes. Research in the US shows that a high-fat diet increases the risk of obesity, diabetes and the development of cognitive impairments. Many converging studies show that a low-fat diet is protective against cognitive decline. And smoking can compromise lung capacity, making it harder to engage in physical activity, which can lead to further health issues and cognitive problems.

We can't prevent cognitive decline – at least, not yet, and probably not any time soon. But there are things we can do throughout our lives that have the potential to increase that cognitive reserve, in the hope of slowing the decline. And research is finding out more about the factors involved.

Some of the changes we can make to live a more 'holistically healthy' lifestyle are little more than common sense. Advice on diet, exercise, smoking →



ABOVE A diet rich in green and leafy vegetables could help you avoid health conditions that can affect cognitive function

RIGHT Combine social and physical activities such as swimming to boost overall wellbeing and stimulate cognitive functions

→ and drinking will be familiar, but less-known lifestyle factors can also affect brain function as we age, including social and sexual connections.

Research indicates that social activities can help slow cognitive decline by challenging people to communicate, which stimulates the mind. You might go swimming with a friend and chat every few lengths, or pass the time of day with fellow dog walkers in the park. Combining social activities with meaningful social connections is a great boost for overall wellbeing, simultaneously stimulating many of our cognitive functions.

SEX ON THE BRAIN

Not often discussed, but equally important for cognitive health, is the importance of maintaining romantic and intimate relationships. Studies have shown a correlation between sexual activity



and cognitive function in men and women over the age of 50. A follow-up study on a group of 73 older adults showed that, overall, higher frequencies of sexual activity were indicative of better scores on tests of cognitive function.

The link between sexual activity and cognitive function could be due to the inherent social connection, or to the release of sex-related hormones such as oxytocin and dopamine affecting brain function.

Dopamine, the so-called 'feel-good hormone', is part of the brain's reward system, promoting positive feelings by connecting learning, memory and emotions. (Intriguingly, research has also linked excess dopamine production with addiction and substance misuse.)

Oxytocin, sometimes called the 'love hormone', is involved in social and sexual interactions, and in bonding behaviours such as those between a



A study involving a sample of Australian adults found notable gender differences in the components of 'cognitive lifestyle' in older age, with women being more likely to engage in social activities, reading and volunteer work. This research shows that sociocultural values and stereotypes drive gender differences across a lifetime, and that these gender-role attitudes can influence cognitive outcomes for men and women in later life.

Sleep is important, too. Many studies show that sleep is significantly linked to cognitive function across a lifetime.

The Medical Research Council Cognitive Function and Ageing Studies (CFAS) have shown that daytime napping is associated with a lower risk of cognitive decline at two- and ten-year follow-ups. Getting less than 6.5 hours of sleep at night is associated with a higher risk of cognitive decline at a ten-year follow-up. Another study has shown that too much sleep and poor quality sleep are both associated with worse memory in men and women aged 65 years and over. These studies all tend to produce similar advice: we should be getting around eight hours of restful sleep each night.

Periods of not sleeping well can contribute to a cycle of negative physical and cognitive health. For example, poor sleep can cause low mood, anger and irritability, which can then impact our relationships, causing further stress – which further impacts sleep. On the flip side, the benefits of sleeping well include improved concentration, creativity, social skills and decision-making.

DENTAL HEALTH, MENTAL HEALTH

Perhaps the most unexpected place where improvements can safeguard cognitive health is your mouth. Research shows that the bacteria associated with gum disease – which affects up to half of UK adults – are also associated with the development of Alzheimer's disease and dementia.

If left untreated, the bacteria causing gum disease can build up and prompt an inflammatory response in the body. Small laboratory studies have shown that bacteria and inflammatory molecules travelling through the bloodstream to the brain comprise one way in which poor oral health can lead to dementia. Large population studies in humans to confirm this relationship haven't yet been conducted. However, to be on the safe side, it's a wise idea to adopt good oral health habits including daily flossing, brushing twice a day and having regular dental check-ups.

So, though there may be no miracle drug on the horizon, there are plenty of things we can do that could help decrease the rate of cognitive decline we experience as we get older. The important thing to remember is that if you're worried about your cognitive abilities, or someone else's, there might be some underlying health issues that can be treated. If you're concerned about your own cognitive function or that of a loved one, seek advice from your doctor, who may be able to help. [SF](#)

"OVERALL, HIGHER FREQUENCIES OF SEXUAL ACTIVITY WERE INDICATIVE OF BETTER SCORES ON TESTS OF COGNITIVE FUNCTION"

mother and newborn baby. Of course, according to the age-old nature-nurture debate, the link between sexual activity and cognitive function could be the combined result of both the social and the biological impacts of intimate behaviour.

There's also good reason to stimulate your brain with challenging activities and hobbies. Reading books and magazines, playing board games, going to museums and playing musical instruments all help combat cognitive decline. Some activities can increase your capacity to learn, and the benefits can spill over into other cognitive abilities, too. For example, activities that include complex memory tests can also improve other cognitive functions such as vocabulary.

Q&A

YOUR QUESTIONS ANSWERED

ALVIN PITTMAN, VIA EMAIL

WHY AM I ALWAYS RUNNING LATE?

Most of us know someone who is perennially late – a person who seems to have a chronic blind spot when it comes to timekeeping. It can become a source of jokey banter among friends, but in another context it can have serious and stressful consequences, from being late for work meetings to missing flights and doctors' appointments.

There could be various reasons why you're perpetually late. Tardiness tends to correlate with lower scores on conscientiousness and neuroticism in personality tests or, to put a positive spin on it, you could just be really relaxed. This might be linked to the way you were raised – perhaps you inherited your parents' relaxed attitude to timekeeping. It might have something to do with your cultural heritage, too. For instance, there's evidence that people in some countries, such as Brazil, tend to be much more relaxed than those in America, for example.

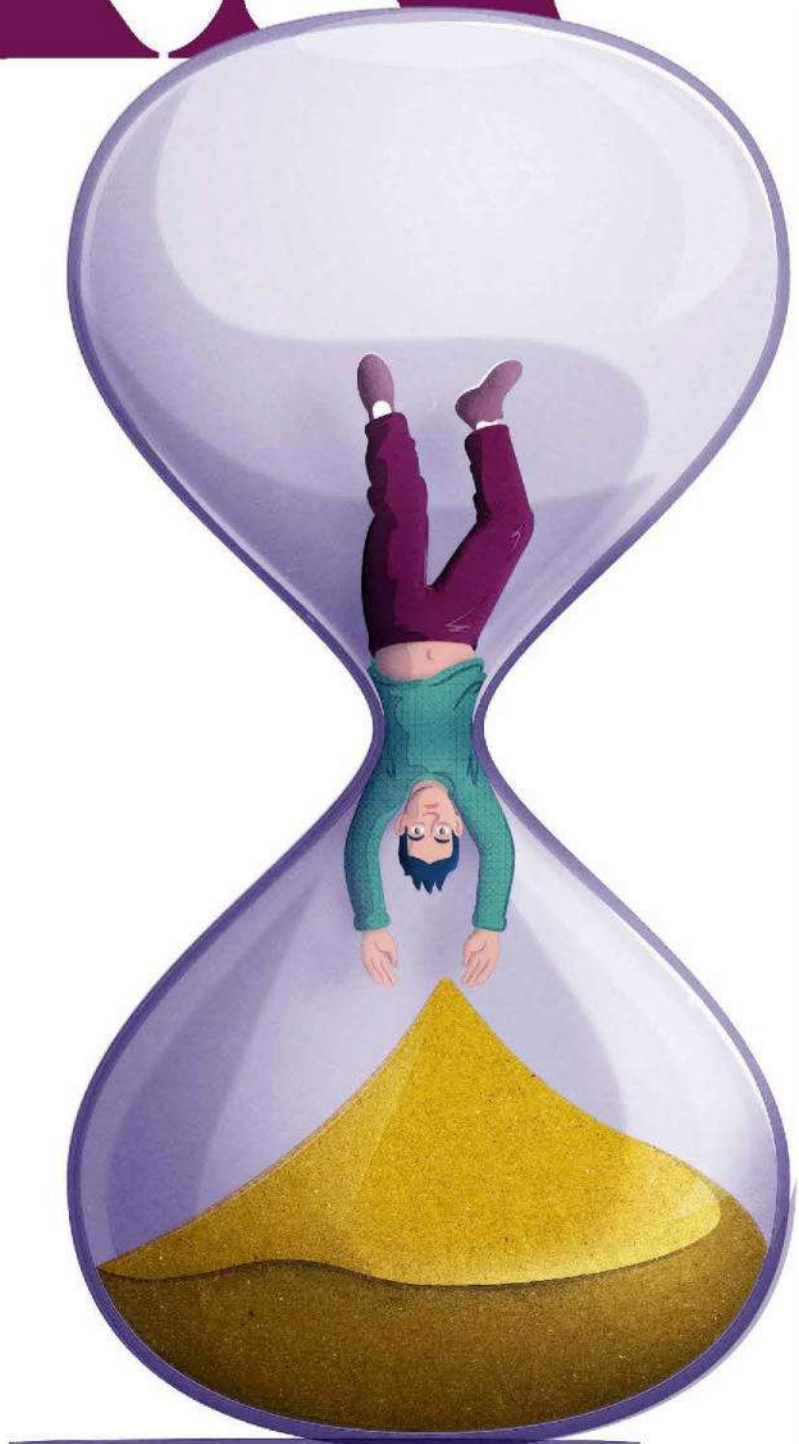
Zooming in on some specific psychological processes, you could be what some psychologists call a 'time optimist' – that is, you tend to underestimate how long things will take. A related issue is procrastination. Getting to places on time means being able to stop what you're doing and prepare to leave. Being a procrastinator might affect your ability to do that in a timely fashion.



PETE LAWRENCE
Astronomy



HOLLY MCHUGH
Health and the human body





DR HELEN SCALES
Marine biology



AMY ARTHUR
Lifestyle and wellness



DR CHRISTIAN JARRETT
Psychology



DR HELEN PILCHER
Biology



LUIS VILLAZON
Geology



DR JEREMY ROSSMAN
Virology



DR ALASTAIR GUNN
Astrophysics



DR CLAIRE ASHER
Planet Earth



IAN TAYLOR
Sport science and sleep

Another mental quirk that could contribute to your problem, at least in some contexts, is overfamiliarity with particular routes – the walk to your local bus stop, for example, or across campus from your halls of residence to a lecture theatre. A fascinating study by psychologists at the University of California and University College London found that we tend to underestimate the time it'll take us to traverse highly familiar physical spaces. So, if your problem particularly manifests when you're planning to travel from A to B on a route you know extremely well, this could be why.

"YOU COULD BE WHAT SOME PSYCHOLOGISTS CALL A 'TIME OPTIMIST'"

One final causal factor to consider is whether you've got an aversion to arriving early. Of course, it's very difficult to plan to arrive anywhere exactly on time, so being punctual usually entails being early – and that can mean twiddling your thumbs. You might not even realise it at a conscious level, but perhaps you hate waiting around.

If these reasons resonate, you can begin to address them. One simple, powerful step you can take is to make a firm commitment not to just be on time, but to be early. Get into the habit of breaking down, in realistic detail, how long it'll take to get to where you need to be, then add on a generous buffer – say, 15 minutes. (The longer the journey, the longer you should make the buffer.) If you don't like the idea of hanging around, think about how you'll spend all this extra waiting time – catch up with text messages, read a book, play online chess or get stuck into a language-learning app, for example. **Q**

ALAMY, GETTY IMAGES ILLUSTRATION: DAN BRIGHT

CALUM COCHRAN, OXFORD

WHAT CAUSED THE GREAT SHEEP PANIC?

According to reports, on the evening of 3 November 1888, thousands of sheep in hundreds of Oxfordshire farms got spooked and bolted. Next morning they were found miles away, cowering under hedges. Two weeks later, *The Times* ruled out "malicious mischief" because "a thousand men could not have frightened and

released all these sheep". In 1921, the science journal *Nature* suggested that lightning might have been a trigger – yet sheep regularly endure storms without panicking. The cause remains uncertain, but whatever did happen most likely led to a turbocharged game of Chinese whispers to account for those numbers of sheep! **HP**



LESTER HERBERT, VIA EMAIL

HOW DOES INSOMNIA AFFECT YOUR DRIVING?

Drowsy driving, like drunk driving, can be dangerous because poor sleep affects hand-eye coordination, vigilance and reaction times. Accurately measuring the effect of a poor night's sleep on road safety is difficult, however. Unlike blood alcohol, tiredness is difficult to quantify. The US National Highway Traffic Safety Administration attributed 1.6 per cent of road deaths (684 fatalities) in 2021 to drowsy driving, though it's been suggested the true figure could be much higher.



A study by the American Automobile Association Foundation for Traffic Safety estimated that getting between five and six hours of sleep almost doubled the risk of a crash, while those who slept for four to five hours had more than four times the crash rate. **IT**

NATURE'S WEIRDEST CREATURES

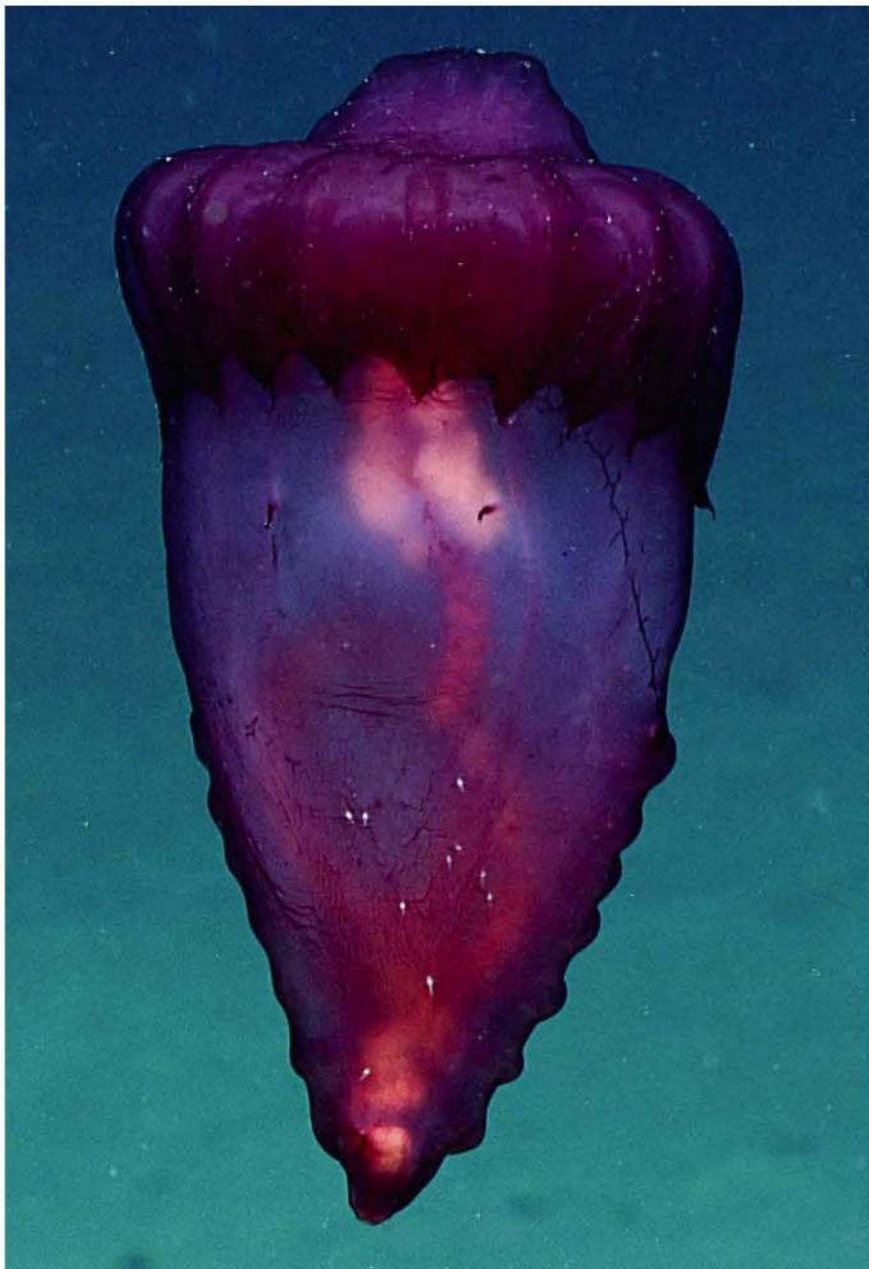
THE SPANISH DANCER

Sea cucumbers are relatives of sea urchins and sea stars (starfish). Generally speaking, they lie about on the seabed and are as inactive as their plant namesakes. In the deep, however, sea cucumbers do things rather differently.

One species, the 'Spanish dancer' – a nod to the twirling skirts of flamenco dancers – is a translucent, ruby-red creature that swims about and drifts on gentle currents in the deep sea, propelled by elegant wafts of its webbed cloak. Another name for it is the 'remarkable dreamer' – a translation of its scientific name, *Enypniastes eximia*.

It's also been given a more grotesque nickname: the headless chicken monster. Admittedly, it does bear a passing resemblance to a plucked fowl carcass that's been flung into the ocean. It's roughly the right size, too, growing to about 25cm (9in) long. The body part that looks like a neck post-decapitation is in fact a mouth, surrounded by a ring of feeding tentacles. When *Enypniastes* lands on the seabed, it uses those tentacles to shovel sediments into its mouth. In common with other sea cucumbers, it feeds on accumulated piles of marine snow – the shower of organic detritus that sinks down from the sea surface, comprising dead plankton and their faeces bound into fluffy particles by a sticky microbial glue.

This swimming sea cucumber was discovered in the 1870s by scientists aboard the HMS *Challenger* during its famous oceanographic expedition. *Enypniastes* lives across all oceans, including near Antarctica, at depths below 500m (1,600ft) and down to at least 6,000m (approx 19,600ft). It's incredibly fragile, being made up mostly of water and specimens tend to get damaged in collecting nets. As such,



scientists only got a good idea of what it actually looks like when it was seen alive for the first time this century, with the help of remotely operated deep-diving robots equipped with video cameras.

Thanks to its watery body, *Enypniastes* is neutrally buoyant and can lift off the

seabed then swim without expending much energy – a key survival strategy in the deep sea, where food is hard to find.

Its coiled digestive tract, filled with pale sediment, is visible through its transparent body. Commonly, just before it launches into the water column, this

"THIS SEA CUCUMBER'S GELATINOUS SKIN LIGHTS UP AND SLOUGHS OFF LIKE A GLOWING CLOUD"



sea cucumber voids its guts and squeezes out a poop of cleaned sediment – a bit like dumping ballast sandbags from a hot air balloon. In this way, *Eynpnastes* plays an important ecological role, mixing up and aerating the seabed just as earthworms do for soils on land.

In common with many other animals living in the deep sea, *Eynpnastes* can illuminate its body – another key survival strategy as it floats about in the dark. If something bumps into it, this sea cucumber's gelatinous skin lights up and sloughs off like a glowing cloud. It's thought to act like a burglar alarm, revealing its attacker's presence to predators of that species, while the sea cucumber itself swims off to safety.

Laboratory studies carried out on living *Eynpnastes* specimens have found that they can quickly regrow their skin and retain their ability to glow in the dark. **HS**

NOAA/OFFICE OF OCEAN EXPLORATION & RESEARCH, GETTY IMAGES

DIANE JOHNSTON, CARDIFF

WHAT REALLY HAPPENED IN THE BERMUDA TRIANGLE?



The patch of sea between Florida, Puerto Rico and Bermuda gained legendary status in the mid-20th century when articles linked it to mysterious disappearances of boats and aircraft. One of the most famous incidents occurred in 1945 when Flight 19, a group of five US Navy bombers on a training mission, vanished in the area. Over the decades that followed, shipwrecks and crashed planes were frequently attributed to the Triangle's destructive forces.

Then, in 1975, Larry Kusche published a book debunking the legend, revealing that reports about the Triangle had been inaccurate, exaggerated or unverified. He concluded that the number of incidents in this area wasn't significantly higher than in any other part of the ocean.

Nevertheless, numerous explanations – both natural and supernatural – have been proposed over the years. Some have blamed leftover technology from Atlantis. Others claimed the Triangle is the site of a space-time warp that sucks objects into a parallel universe. One of the strangest natural explanations is that bubbles of methane released from the seafloor were capsizing ships. However, studies by the US Geological Survey record no significant methane releases in the past 15,000 years.

The high incidence of hurricanes in the region could have had serious impacts in the era before accurate forecasting enabled pilots and captains to avoid bad weather. A recent study suggested that converging

storms might generate rogue waves up to 30m (almost 100ft) high that could sink even large boats. Laboratory simulations confirmed that such waves would have ship-sinking potential, but there's no evidence they actually occur in the Bermuda Triangle.

Some claim that magnetic anomalies caused sailors and pilots navigating by compass to veer off course. Although no such anomalies have been identified, in the early 20th century true geographic north and magnetic north aligned in the Bermuda Triangle, which could have led to navigational errors.

It's worth noting that the US Coast Guard doesn't identify any specific hazards in the Bermuda Triangle, and a 2013 study listing the most dangerous waters for shipping didn't feature the region. Despite a high volume of air and sea traffic, as well as frequent hurricanes, the Bermuda Triangle hasn't experienced a statistically unusual number of crashes and wrecks.

The real reason this legend has proved so persistent is much more mundane. People are naturally drawn to mystery, so early reports of disappearances attracted widespread attention. Once the myth was established, reporters were quick to attribute more wrecks to the Bermuda Triangle's mysterious forces. The frenzy has subsided in recent years, perhaps because modern technology allows us to track ocean and air traffic with greater precision. **CA**

ROSE BARNETT, ENFIELD

WHY DOES BEING KIND MAKE YOU FEEL GOOD?

It seems obvious to say that being on the receiving end of kindness makes you feel good. But, while a kind act can't provide you with any calories, it's not simply a throwaway experience. When someone is surprisingly kind to you – a stranger holds open a door for you, or your coffee is 'on the house' – the act triggers activity in the nucleus accumbens, an area of the brain often referred to as the pleasure centre.

In 2021, more than 60,000 participants completed the Kindness Test questionnaire online. The results showed that carrying out kind acts had benefits for wellbeing. Whether you're giving or receiving kindness, you're likely to feel better.

People who regularly volunteer or donate money to charities talk of the warm glow they feel from their good deeds. This 'helper's high' corresponds to brain activity: being kind has been shown to release oxytocin and serotonin, hormones well known for their pleasurable effects on mood. Of all the kind acts, volunteering provides among the biggest benefits for giver and receiver alike; indeed, one large meta-analysis of studies showed that



regular volunteering reduced the risk of dying by around a quarter.

Kindness at home has impacts, too. One study of 59 women found that a hug with a partner lowered resting blood pressure and heart rate.

Studies have also shown that simply noticing kindness and feeling gratitude has positive impacts on the body, boosting the nervous system's ability to lower a fast heart rate and helping to reduce blood pressure in people with hypertension. Those who keep weekly gratitude journals have been found to enjoy improved measures of wellbeing: they exercise more often, and report feeling physically healthier and more optimistic than those who don't.

Even smiling at strangers can make you feel happier, as a grin has been found to spark positive feelings in the person smiling.

Kindness helps both the body and the mind. People who were told by researchers to carry out nice acts for others reported feeling more confident, competent and purposeful while being kind – even though they weren't being completely altruistic. So it seems that if you decide to start spreading a little more kindness in the world, you'll quickly reap the benefits.

Kindness doesn't have to involve a lot of time, money or effort. Here are some simple ways you can practise being more kind that take next to no time at all:

- Send a thank you email to someone you've worked with
- Offer a compliment to a stranger
- Make a cup of tea for a colleague
- Buy a small gift for a friend or donate to a charity on their behalf
- Text a family member to let them know you appreciate them
- Think about something you're grateful for

Kindness really is important. It builds our empathy, fosters deeper relationships, incites positive feelings and promotes good heart health. It's contagious, too – by being kind, you'll influence the people around you to be kinder, so they'll also enjoy all the aforementioned benefits. **AA**

CONRAD GORDON, VIA EMAIL

I LOVE NOTHING MORE THAN DONNING LYCRA AND HITTING THE ROADS ON MY ULTRA-LIGHTWEIGHT, PROFESSIONAL-GRADE BIKE. SHOULD I BE SHAVING MY LEGS?

Marginal gains are important to cyclists. Riders ranging from Team GB athletes to steely-eyed commuters optimise their nutrition, equipment and positions just to shave a few seconds off their times. So it's no wonder that some MAMILs (that's middle-aged men in Lycra) would also be interested in shaving their legs.

The theory is simple enough: removing the hairs on your legs reduces drag, the frictional force that applies resistance to any object moving through air. On a bike, air resistance is the number-one factor slowing you down (unless you're riding uphill, in which case gravity is quite literally pulling you back).

As you ride forwards, you displace the air molecules in front of you – that's the



'wind' you feel. Aerodynamic design is all about optimising the flow of that air as it moves around you, to reduce the drag slowing you down. It's the reason why cycling helmets are shaped like sports cars, why riders wear skinsuits and why pro cyclists adopt a riding position in

which their bodies sit as low and flat as possible over their bikes.

Could the hairs on your legs really make *that* much difference to your speed? That's much debated among riders and engineers alike, but one study by bike manufacturer Specialized caught the eye.

Having shaved a rider's legs, the research team tested him in a wind tunnel and found that his dolphin-smooth appendages reduced drag by a healthy 7 per cent. Over the course of a 40km (25-mile) time trial, that saving would theoretically provide a 79-second advantage over an opponent with au naturel legs. Enough for a pro rider to seal a victory and to ensure you get the good spot in the bike rack at the office. **IT**

ALAN RHODES, VIA EMAIL

IS IT TRUE THAT GORILLAS ARE PERMANENTLY FLATULENT?



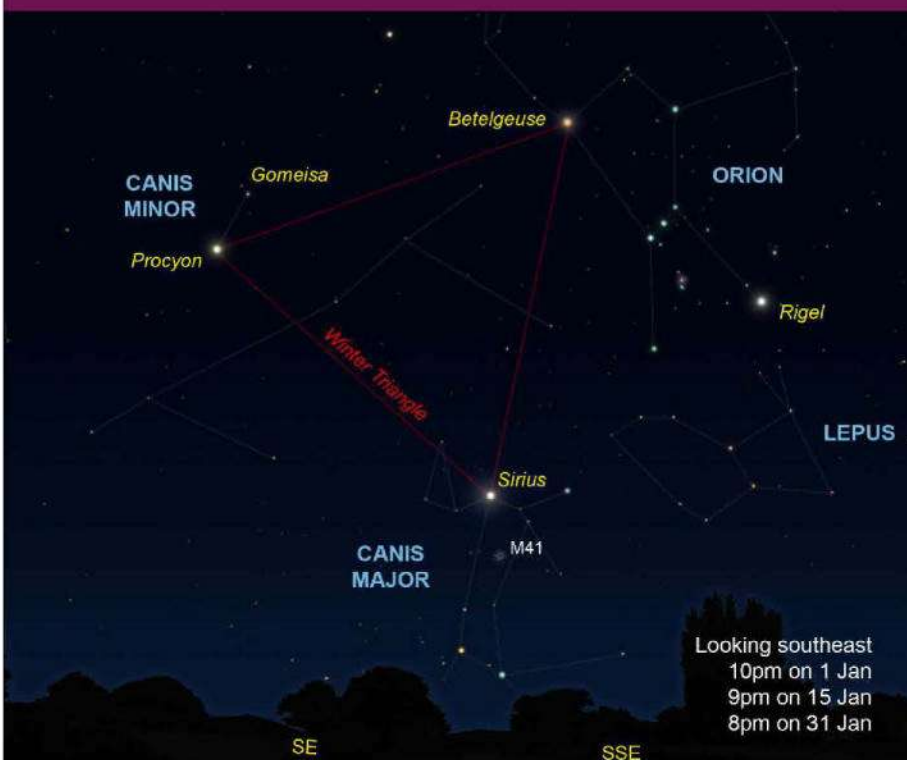
Hamsters do it. Horses do it. Humans do it, of course. No surprise, then, that gorillas – among our closest living relatives – also trump. A lot. Farting is the body's way of ridding the intestines of unnecessary gas produced by gut bacteria. Odourless gases such as carbon dioxide, hydrogen and methane are released, sometimes along with volatile sulphurous components that can taint the offending emissions with a whiff of egg.

There are two species of gorilla, eastern and western, both native to the forested regions of equatorial Africa. Weighing up to 190kg (420lbs), the world's largest living primates mainly eat plants that are fibre-dense and comparatively nutrient-poor – so need to munch about 20kg (44lbs) of nettles, wild celery and other vegetation daily, spending much of their lives foraging.

When gorillas aren't eating, they're resting; and when they're resting, they're digesting. "This is when you can hear lots of flatulence," says Jordi Galbany Casals of the University of Barcelona, who studies the mountain gorilla (a subspecies of eastern gorilla) in Volcanoes National Park, northwest Rwanda.

In 2020, the BBC series *Spy in the Wild* revealed just how much these animals toot. A remotely operated 'gorilla cam' was used to film mountain gorillas in Uganda. Gorillas sing as they eat, it turns out – and their dining is interspersed by near-constant bursts of trumping. "Gorillas do have lots of flatulence all the time," says Galbany Casals. **HP**

ASTRONOMY FOR BEGINNERS



Looking southeast
10pm on 1 Jan
9pm on 15 Jan
8pm on 31 Jan

THE GREAT AND LITTLE DOGS

WHEN: THROUGHOUT JANUARY

There are several dogs represented in the night sky, the best known being Canis Major, the Great Dog. To spot it, start by finding its master, Orion – specifically, the three belt stars at the centre of that constellation. Extend their line down and left (southeast) to arrive at Sirius, the alpha star of Canis Major.

Known as the Dog Star, Sirius is a fairly close neighbour of the Sun, located 8.6 light-years away (one light-year being the distance light, travelling at nearly 300,000km/s, covers in a year – almost 10 trillion kilometres). It's the brightest star in the night sky, mostly because of its relative proximity to Earth. Sirius doesn't get very high above the UK's horizon, so its light is heavily influenced by atmospheric turbulence. This causes it to flicker, often displaying strong colours.

Canis Major is a fairly good representation of a dog – it's easy to imagine the lively animal running up towards Orion. It has a pointed head to the upper left (northeast) of Sirius, a

distorted rectangular body that slopes down and left of the star, and even a small tail, although that appendage and the dog's back legs are very low in the sky when viewed from the UK. To spot them using binoculars, look below (south) of Sirius by just under a binocular field of view. Given a clear, dark sky you should also see the lovely open cluster Messier 41 (M41) within the dog's body.

To locate Canis Major's companion, Canis Minor – the Little Dog – head up (north) from Sirius and left (east) into a relatively sparsely populated area of sky, with just one bright star. This is Procyon, the brightest star in Canis Minor. This constellation is less identifiable as a dog, basically formed from just the two stars, Procyon and Gomeisa. **PL**



by PETE LAWRENCE
(@Avertedvision)

Pete is an astronomy expert and presenter on The Sky at Night.

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SUDIRMAN, MALAYSIA

IF WE EXTRACTED AND USED ALL OF THE FOSSIL FUELS ON EARTH, WOULD THE PLANET BECOME LIGHTER?



Burning a fossil fuel doesn't get rid of it – it just gets converted into water, carbon dioxide and ash. Aside from the tiny fraction of hydrogen made from natural gas that subsequently escapes from the atmosphere, and the even tinier fraction that's used as fuel to power rockets in deep space, all of the mass remains here on Earth. In any case, the roughly 1.5 trillion tonnes of fossil fuel reserves represent less than one ten-billionth of one per cent of Earth's mass. Proportionally, you lose 500 times more of your body weight each time you shed an eyelash. **LV**

NATALIE HUDSON, BRIGHTON

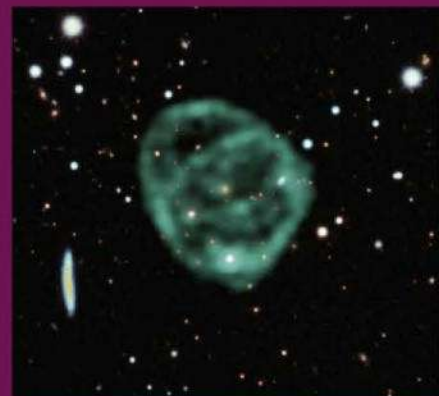
WHAT IS A FAIRY RING?

Mushroom circles had magical significance in ancient folklore, being attributed to witches, dragons or dancing fairies. But there's a natural explanation. Commonly known as fairy circles or pixie rings, each comprises a single fungus connected underground by threads called mycelia. When a fungal spore germinates, mycelia radiate out to absorb nutrients from the soil. As nutrients in the centre are exhausted, that part dies, creating an expanding ring. Mushrooms then sprout around the perimeter in late summer or autumn. Some fungi create a central 'dead zone' whereas others fertilise the soil, generating a circle of lush vegetation. **CA**



BRENDAN OWENS, BRADFORD

WHAT ARE ODD RADIO CIRCLES?



Odd Radio Circles (ORCs) were discovered by accident in 2019. They are circular regions of faint, edge-brightened radio emissions that are invisible at optical, infrared, ultraviolet and X-ray wavelengths. Some have a galaxy at the centre while others don't, but they're all characterised by their large size, many times bigger than a typical galaxy. Some ORCs seem to have a double-ring structure whereas others are single. Some also have internal arc-like structures that appear to be associated with galaxies embedded within the bubble of radio emission. Objects with a high degree of spherical symmetry are common in the Universe, but ORCs appear to be different from all of those, leading astronomers to declare them a new class of object.

ORCs may be a form of spherical shock wave created by, for example, fast radio bursts, gamma-ray bursts or neutron star mergers. If so, they would have to be extremely ancient to have expanded to such large sizes. Alternatively, they may be associated with the jets of material coming from the central regions of radio galaxies – but, again, their large size, and the fact that not all of them have central objects, are difficult to explain.

A promising idea is that ORCs are formed by the merger of two supermassive black holes in a central galaxy. The available data is also consistent with a shell caused by a 'shock termination' from a wind of energetic particles from a central 'starburst' galaxy. Another suggestion is that ORCs are the throats of 'wormholes' – theoretical passages through space-time. But astronomers are yet to reach agreement on the true nature of ORCs. **AG**

FAIZAN HOLLAND, CHICHESTER

HOW CAN EMBRACING BIOPHILIA LEAD TO A RICHER, HAPPIER LIFE?

The term biophilia, meaning 'love of living things', describes an innate desire to connect with nature. Scientists believe that this is the reason why many people feel calmer and happier in a natural setting, and that embracing biophilia – by bringing plants into our homes or offices – could boost our mental wellbeing. There's plenty of scientific evidence to support this theory. One study found that introducing plants into ordinarily sparse office environments can make staff happier and increase productivity by 15 per cent. But why?

One of the main benefits of a green workspace is its impact on stress. Adorning an office with plants isn't just visually pleasing; seeing greenery also helps us tap into our biophilic connection and has a calming effect on the brain, nurturing positivity, relaxation and a greater sense of wellbeing. Plants can also help absorb and



dampen sounds in indoor environments, thus reducing distractions from noisy work colleagues and creating a quieter, more peaceful atmosphere.

Another reason why houseplants are beneficial in the office is because they enhance air quality. Plants release moisture into the air through transpiration, elevating humidity and mitigating many of the problems caused by dry air – including general discomfort, stress and health issues such as headaches and dry eyes. Plants also act as natural air purifiers, removing toxins

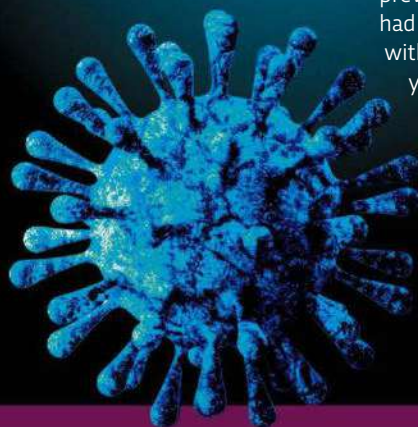
and carbon dioxide, while emitting oxygen during photosynthesis. This cleaner, oxygen-rich air boosts brain function and alertness.

Despite the evidence that nature and greenery are good for our health and wellbeing, many modern offices are open-plan, minimalist and devoid of plant life. However, it is encouraging to see more and more forward-thinking companies embracing the power of nature by incorporating more greenery into the workplace. **HMH**

QUESTION OF THE MONTH

SIMON FOSTER, VIA EMAIL

I'VE HAD COVID, PLUS ALL THE VACCINES – HOW LONG WILL MY IMMUNITY LAST?

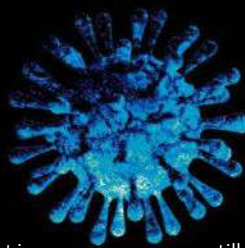


As COVID-19 case numbers rise during the UK winter, one big question is on many people's lips: will I be protected if I've been infected and have had a full course of COVID-19 jabs? This combination of vaccination and previous infection produces hybrid immunity and appears to generate more lasting protection than either vaccination or infection alone.

Protection from severe COVID-19 isn't the same as preventing infection. If you've had COVID-19 and all your jabs within the past 12 months, then you're probably quite well protected from severe disease. One year after the last infection or booster jab, protection against severe disease wanes, but persists to some degree. Overall protection from infection is less clear-cut. We know

that, for most people, hybrid immunity provides good, but not total, protection from infection for about eight months, though effectiveness is highest in the three months following an infection or booster jab. Protection also varies between individuals, and depends on the variant with which they were infected, and the type of vaccines they had. Duration of protection is also affected by virus evolution – typically, the more the virus changes, the faster the protection wanes.

We also know that vaccination reduces the likelihood of getting long COVID after an infection, but is only partly effective – and we don't know how long this protection lasts. Previous infection seems to actually increase the risk of



long COVID. At present, we don't know how well – or if – hybrid immunity protects against Long COVID. COVID-19 jabs are still one of the most effective forms of prevention, but no single measure is perfect. Best combine the tried-and-true measures: vaccination, mask-wearing and avoiding crowded indoor spaces. **JR**

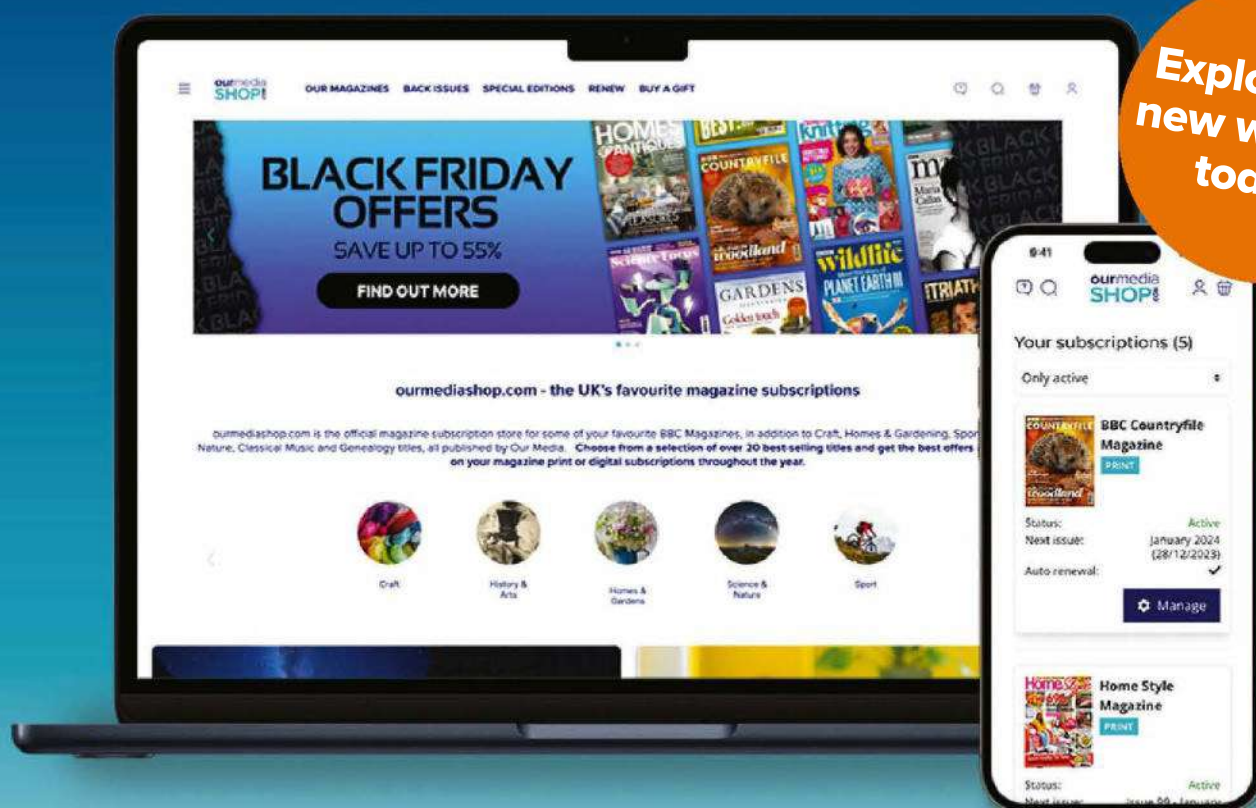
WINNER

The winner of next issue's Question of the Month wins a trio of hardback popular science books: *Most Delicious Poison*; *Mapping the Darkness*; and *White Holes*, worth over £50.

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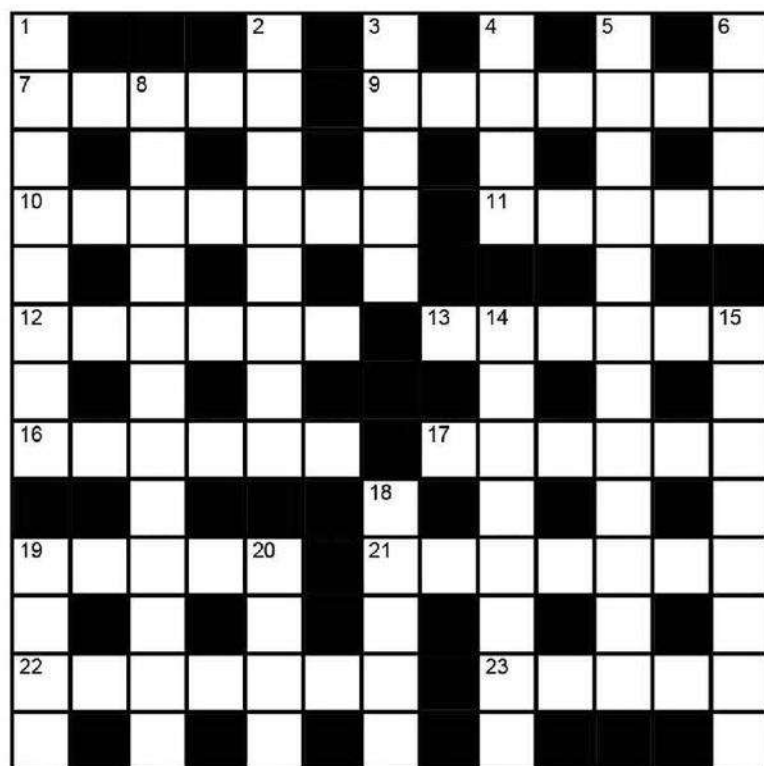


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CROSSWORD

PENCILS AT THE READY!



ACROSS

- 7 Back-to-front, entered bar (5)
- 9 Musical reduction shows top style (7)
- 10 Team with weapons at its disposal? (7)
- 11 Fastening in wet conditions (5)
- 12 Volunteers to put one on pale island (6)
- 13 Wager everyone comes in for dance (6)
- 16 Circular, small sandwiches (6)
- 17 You and I organised sale for animal (6)
- 19 Stick to personnel (5)
- 21 Surgical instrument is an afterthought, after coercion (7)
- 22 Personal interaction - no attempt on English dress (7)
- 23 Saucy dance? (5)

DOWN

- 1 Man returns to stare around catastrophe (8)
- 2 Usual flag (8)
- 3 Explosive found on the beach (5)
- 4 Tim's lost in lack of visibility (4)
- 5 He chills cocktail with a swimmer - a weakness (8,4)
- 6 Deepest yellow around inflammation (4)
- 8 Lucia gets worried - Edward waved (12)
- 14 Medical problem affected many, sure (8)
- 15 Thanks to Milan's strange charm (8)
- 18 Suggest removing front of strongbox (5)
- 19 Fire in container (4)
- 20 Sheet of metal to prevent success (4)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.

DINOSAUR EVOLUTION

Our dino depictions are growing more accurate.
But they haven't always been so reliable



PLUS

GOING BEYOND THE BLACK HOLE

Suppose you could cross the event horizon
and survive... what happens then?

BODY DYSMORPHIA IN THE DIGITAL WORLD

How avatars and AI filters are fuelling
people's fears about their appearance

ON SALE 19 JANUARY



COLD SHOCK THERAPY

Could throwing open your windows this winter improve your health by welcoming in the cold, fresh air to blow out pollutants?



Take a deep breath... But, as you do, think about what you might be inhaling, especially if you're reading this at home. Indoor air pollution is becoming a hot research topic as evidence mounts that our homes are awash with a miasma of undesirable particles. For example, nitrogen dioxide released by gas hobs has been linked to a shocking number of child asthma cases. And British researchers found that wood burners can triple the pollutants in a home.

Next, read the small print on your cleaning products or the paint on your walls – many contain volatile organic compounds or carcinogenic chemicals. Meanwhile, damp and mould release fungal spores that can be harmful to people with allergies or compromised immune systems. And that's before anyone lights a cigarette or coughs COVID-19 into your living room.

Pollutant concentrations can be two to five times higher indoors than out. Indoor pollution is linked to cardiovascular, respiratory and neurological conditions, and it's estimated that exposure to particulate air pollution causes tens of thousands of premature deaths in the UK annually.

"OPENING THE WINDOWS, EVEN FOR A SHORT AMOUNT OF TIME, HELPS FLUSH OUT POLLUTANTS, SPORES AND VIRUSES"

So, what to do?

Well, here's a breath of fresh air from our friends in Germany: open the windows, even in winter, and you'll encourage nasties to waft out. Germans take ventilation very seriously, with many practising *Stoßlüften* – 'shock ventilation' – flinging open windows like Ebenezer Scrooge on Christmas Day, every morning and evening, whatever the weather.

Stoßlüften is gaining traction in the UK and elsewhere, especially post-COVID and as research about indoor pollution builds. It's a simple idea: opening the windows, even for a short amount of time, helps flush out pollutants, spores and viruses, and improve our long-term health.

Experts are certainly on board.

"Good ventilation is good for your health for lots of reasons," says Prof Tim Sharpe, head of architecture at Strathclyde University. "The challenge comes when it's cold outside, heating is expensive and buildings are thermally poor. Then people can be forced to choose between heating or ventilating."

Rather than having a little ventilation all the time, Sharpe says, *Stoßlüften* involves opening all of your windows at once, as wide as they'll go, and flushing fresh air through for a short period. To air with flair, he recommends opening windows at the front and back of your home (if it's dual aspect) to let air flow through. Focus on humid bathrooms and kitchens, where moisture can build up. Also pay attention to the direction of the wind and what it might carry.

"Sometimes pollution comes in from outside," Sharpe says. "If you're next to a busy road, fumes will get in as well."

To avoid losing too much heat, limit how long you ventilate. If you let walls and other surfaces become cold, it'll make your home more difficult to reheat, Sharpe says.

For a good case study, look to Wiesbaden, western Germany, where a pair of researchers monitored what happened when they opened all of the windows in a classroom. When the temperature outside was between 7°C and 11°C (45-52°F), they found that 98 per cent of aerosols left the room within two minutes. In that time, the internal temperature dropped by 6°C (about 11°F), but stabilised within seven minutes of closing the windows.

Sharpe believes that we should embrace a little cold therapy: "Any kind of air movement is seen as a draught and a nuisance these days, when actually a bit of fresh air is good for you in a lot of ways."

The weather outside may be frightful, but the fire inside is releasing potentially harmful particulates into the air you breathe. Which would you prefer? **SF**

TAKEAWAY ADVICE

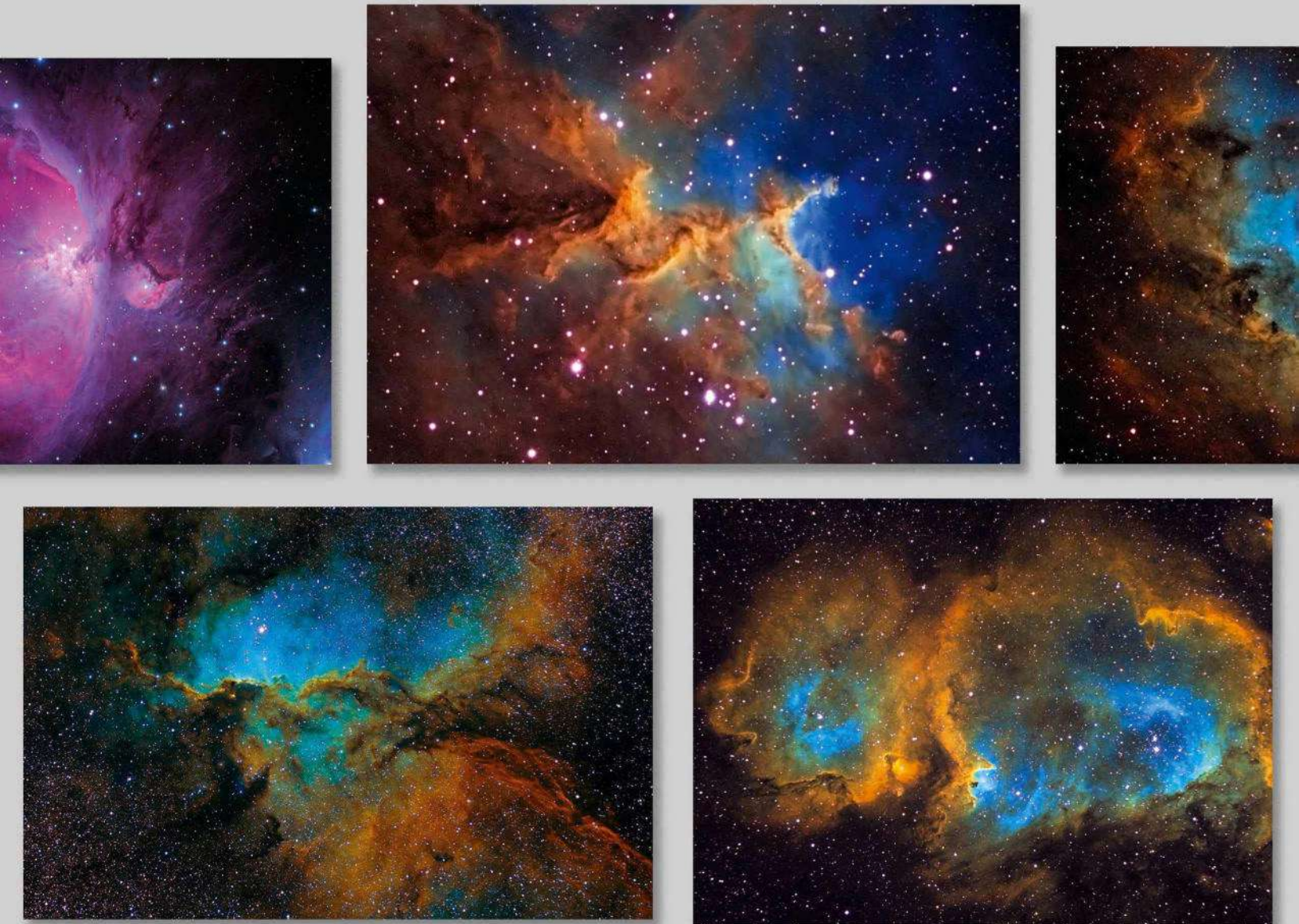
Flinging your windows open for five minutes of very fresh air could do you a world of good, particularly if you stay indoors during the day

by **IAN TAYLOR**

Ian is a freelance science writer and the former deputy editor of BBC Science Focus.

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